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CONTENTS AND INDEX

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CONTENTS.

VOLUME I, 1914.

For alphabetical index, see page v.

No. 1. JANUARY.

No. 2. FEBRUARY.

No. 3. MARCH.

No. 4. APRIL.

No. 5. MAY.

No. 6. JUNE.

No. 7. SEPTEMBER.

No. 8. OCTOBER.

No. 9. NOVEMBER.

No. 10. DECEMBER.

INDEX.

VOLUME I, 1914.

ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors are printed in *italics*.

Vol. I JANUARY, 1914 No. 1

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

BOSTON FOUNDATIONS.

BY J. R. WORCESTER, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

TO BE PRESENTED JANUARY 28, 1914.

THE excuse for this paper will be found in the Appendix, in which is collected certain information as to the nature of the ground in Boston and the immediate vicinity as determined mainly by wash borings. The reason for relegating to an appendix the most important part of the paper is that it is a dry collection of facts, not productive of discussion, which will not be read, but which may be useful for reference.

While the geological conditions in this district are relatively simple, different parts of the territory vary enough to render an approximate knowledge of the soil formations essential before any designs of foundations can be attempted. It is believed that with the information collected here, one may form an idea of the general nature of the ground in most parts of the territory covered by the maps. Certain tracts may look bare, but generally the bare places are where the ground is so good that borings are not so much needed. It is not to be expected that sufficient information can be obtained from this collection to obviate the necessity of further borings, but it will assist in determining the general conditions.

A paper on this subject of "Boston Foundations," contributed to the Society January 28, 1903, and published, with the discus-

NOTE. This paper is issued in advance of the date set for its presentation. Discussion is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before March 15, 1914, for publication in a subsequent number of the JOURNAL.

sion it elicited, in the *Journal of the Association of Engineering Societies*, June, 1903, described common practice in the construction of foundations of buildings and other structures, and included a report of numerous borings in the Boston peninsula. The present article includes and supplements the boring data of the earlier paper, and briefly treats of certain other information which has been accumulated in ten years' experience, including a few loading tests of piles and soil.

Changes in Building Law.

An interesting development of the decade was the revision of the building law which was enacted in 1907. It will be recalled that in 1903 we were hampered by certain provisions of the old law, particularly that requiring the capping of piles with block granite levelers and that allowing no reduction of live loads in foundations of buildings. The revision of the law brought about modifications in both these provisions. It is significant, however, of the continual progress of engineering science, that the law of 1907 is now behind the times in many respects and sadly needs further amendments. The changes now most needed from the engineering point of view are in the provisions with regard to the use of concrete, as it is in the use of this material that most rapid changes are taking place. It was suggested in the discussion of the earlier paper that action by our Society might produce beneficial results with regard to the law, and it may not be out of place now to suggest that if we should take the initiative we might obtain improvements which would be of great service to the community. This matter, however, is apart from the main subject.

Geological Formation.

Further experience with the general nature of the formation of the ground hereabouts has drawn attention to three important conditions not well described in the earlier paper.

First, the composition of the underlying bed of earth upon which most of our foundations rest. This was described as "clay, free from grit, but containing a large proportion of quartz

flour, with occasional thin layers and streaks of very fine sand, with occasional angular fragments of rock." In many places this description fairly describes the material encountered, but, within the original shore line there appears to be more of the fine sand formation than would be expected from this statement. In the deep excavations under the Filene Building, at the corner of Washington and Summer streets, a stratum of clay and gravel from 10 to 20 ft. in thickness was encountered, below which the material was mostly sand of varying degrees of fineness. Most of it was very fine, the grains having a diameter of from .003 in. to .005 in. When in its natural bed, saturated with water, it had much the appearance of blue clay, showing similar color, hardness and toughness. It would generally stand for some time with a vertical face even at considerable depth, but in most places it would slowly flow and in some it flowed with quite a rush. It would not stay long in suspension in water but would quickly settle when allowed to stand. When dry, it became light gray in color, and when magnified the particles appeared as nearly clear, round crystals. Under the Jordan Marsh Company Annex, between Avon Place and Bedford Street, a similar sand was encountered, but much yellower in color. The Cambridge Subway tunnel under Beacon Hill was driven through an extremely hard bowlder clay with occasional thin streaks of sand in its deepest part, but as it approached the surface the material changed to fine sand.

Second, the consistency of the deep clay formation. This appears to vary in different parts of the Boston Basin. Under the Boston peninsula it is generally fairly hard even near the shore line. In the deep foundations under the Custom House, though fine sand was encountered in places, the greater part of the depth, down to the bowlder clay 33 ft. thick overlying ledge, that is, to about grade —85,* the material was blue clay which gradually increased in hardness with the depth. On the other hand, under a section of Cambridgeport and a part of the Back Bay the material is extremely soft, so soft, in fact, that it apparently is quite free to flow from heavily loaded areas towards places where the load is less. It is not definitely determined, so

* Referred to Boston Base, which is 0.64 ft. below mean low tide.

far as the writer knows, whether such a flowing takes place, or the clay is gradually being compressed. It is certain, however, that widely-spread settlements have occurred, in some instances to a very marked extent. A section of Cambridgeport covering about one-half square mile, centering roughly on Massachusetts Avenue and Albany Street, has settled to a maximum amount of about 2 ft.* In Boylston Street, between Berkeley and Clarendon streets, the Transit Commission found the well-preserved remains of a weir or fence at about grade —18. It does not seem possible that this could have been constructed below low-tide level or grade 0. Near Church Street was found a well-preserved stump of a tree with roots, at about grade —15. Another instance of subsidence is found in the depth at which peat is encountered. This material must have been formed above water, but is now found, overlaid with silt, far below grade 0. On Tremont Street, above Dover, it was found at about grade —12, and on Boylston Street it has been found at grade —19. This tendency to settle will have to be taken into consideration in locating heavy structures in the future. It is not enough to gain the necessary support in piles which may rest in a gravel crust, but the settlement of the crust may seriously injure important structures, as it is believed to have already done in the case of the Public Library and the New Old South Church.

Third, the danger in mistaking silt for clay. In many places in the city the filling has been put upon a bed of silt from 10 to 20 ft. deep. This silt is very easily mistaken for blue clay. It has nearly the same color, though a little more bluish and not so green in hue. It is tough, nearly impervious to water, soft and smooth to the touch, and when dry is very hard. It usually contains small shells, which are not found in the clay, but otherwise it is dangerously similar. The danger lies in the two facts that the silt is compressible and that it is generally underlaid with peat. Both of these causes render it unsafe for supporting foundations.

* This statement, based on the authority of Mr. L. M. Hastings, city engineer, is at variance with the findings of Prof. W. O. Crosby in a recent report on the land on which the new buildings of the Massachusetts Institute of Technology are being erected.

Ground Water Level.

Another important change which has occurred in the conditions surrounding Boston has been caused by the construction of the Charles River Dam, by which the river above the dam is maintained at a constant level of about grade +8. This would seem to warrant a higher level for cutting piles in those parts of the Basin which drain into the Charles River above the dam. The writer is of the opinion that, except where leaky sewers at a lower level drain the ground, or where the ground water is being pumped, it is safe to count on its never standing at a lower level than it does in the basins into which the surplus must drain. This theory is not backed by any comprehensive series of experiments, though the long experience in Boston of cutting piles at the average tide level with entire safety gives some evidence of its soundness. The main argument in its favor, however, is that the rainfall is always in excess of the evaporation, and the surplus water in order to escape must have some head above its outlet. Against this theory it has been argued that in a closely built city so much of the surface is covered with buildings and nearly waterproof paving, only a small proportion of the rainfall can soak into the ground, the most being carried away by storm drains. The answer to this line of reasoning is that though the waterproofed areas keep water out of the ground, they also keep it in by preventing evaporation.

Certain instances have been noted where the ground water level appeared to be far below the outlet, but the writer believes that the cause can be explained without invalidating the theory. One of the most marked was when the borings were made in the vicinity of the old Custom House, where it was reported that the water would not rise in the pipes above about grade —30. It was found, however, that when excavations were allowed to fill, the water rose fully to mean tide level. The writer believes that the trouble with the borings was that sufficient time was not allowed for slow seepage through nearly impervious ground. Another case was reported in Brimmer Street, where in an open excavation the ground water level for many months was as low as +3, or 5 ft. below the surface in the nearby Basin. This case

has seemed to the writer to be one of leaky sewers. At any rate, ancient piles recently uncovered in this immediate neighborhood have been found to be well preserved as high as grade +10. In numerous cases the ground water level has been lowered over considerable areas by pumping from deep excavations. This has been very noticeable in Boylston Street and vicinity during the construction of the subway, but here, as elsewhere, it has been found that the normal grade is reached after a time when pumping is suspended. It also sometimes occurs that in an open excavation no trouble is experienced with water until a depth is reached considerably below what might be assumed to be the normal level. This has given the impression that the water level had not been reached, though the cause is simply that the material is impermeable and that, though damp, there is no flowing water. Under such conditions, if time enough is allowed without pumping, water will appear and will rise to the expected grade. In the construction of the Commonwealth Pier, Mr. Hodgdon has adopted +9 as the grade at which to cut buried piles. While this may seem to be rather high, where the mean tide level is +5, it would seem unlikely that near the shore line the ground could ever dry up enough at this level to endanger the piles. In view of present knowledge, we may ask whether grade +8 would not be a reasonably safe assumption for low ground water level.

The writer hopes that this point will be fully discussed and that all facts bearing upon the subject will be brought out. It is important not only in determining the safe elevation for cutting piles, but also to determine the possible head that may act on a waterproof floor at low grade.

Basement Floors.

The subject of basement floors is perhaps a little apart from that of foundations, though so closely allied that we may be pardoned for going into it briefly. One of the commonest mistakes in building construction has been to rest walls and columns on piles, when the soil is soft, and to place the basement floor directly on the ground. The usual reasons for doing this are that it is a great saving in first cost, that it is not expected that

the basement will be used extensively, and that it is thought that the weight of the basement floor will be so little that it will not settle even on very soft ground. The results are that in a few years the ground shrinks through the decomposition of organic matter and the floor must necessarily follow. When it is partly attached to walls and columns, as is usually the case, it will crack and drop in the center, forming hopper-like depressions. The writer has seen numerous cases where the settlement has been from 6 in. to 1 ft., and has heard of a case where, in a dwelling-house, the furnace sank 18 in. Where the basement floor is below ground water level these settlements are sure to produce leaks; where above water, they may not be so serious, but it is very desirable to have such floors cut free from piled supports by liberal vertical joints so that the floor may settle in all parts alike. The best way is to give the floor strength enough to sustain itself and its live load, carrying this weight to the piles. If this course is pursued, however, we have a condition where full account must be taken of hydrostatic head acting on the under side of the floor, for a space will soon be left between the floor and the earth which, if the water level is higher, will be filled with water, and it then becomes important to know the maximum head which can occur.

Hydrostatic Pressure.

There have been many examples of water pressure raising floors, showing that it is an actual not a theoretical condition with which we have to deal. The maximum head has not, so far as the writer knows, been definitely ascertained. In the Back Bay district the streets are at grade 16 or 17, and as the ground water level does not rise to the street grade we have an upper limit and, if the foregoing reasoning is correct, a lower limit between which it is to be located; but they are 8 ft. apart, and this range of uncertainty should be reduced considerably. The writer has assumed grade 12 as the highest water level in many instances, and has not learned of a case where this height has been exceeded on the Basin side of the city. Near tide-water, provision must be made for extreme tides, which may reach to about grade 14.

In this connection, it may be well to consider how large a

proportion of a floor resting on the soil need be assumed to be exposed to water pressure. As has been said above, if the floor is supported on piles, practically the whole area is liable to be so exposed, but when the floor rests directly on the ground, obviously less than the whole area is exposed to water, for part must bear on the soil. Experiments reported by J. C. Meem (Trans. Am. Soc. C. E., Vol. LXX, p. 362) would indicate that with a sandy soil not over 50 per cent. is so exposed. The writer has been in the habit of making this assumption in Boston, — though realizing that it is purely an assumption, — and has yet to hear of its not proving adequate. He would be very glad of further information on this point.

Concrete.

Since 1903, concrete has almost completely taken the place of stone for foundations, except where exposed to sea-water between high and low tide. Its cheapness and convenience and the ease with which it can be reinforced to resist tensile stresses have given it the place formerly occupied by other forms of masonry and have also nearly driven out of use steel beams and girders in grillages and cantilevers.

Reinforced concrete is wonderfully adaptable to foundations in many ways. Its strength permits the use of thinner walls and slenderer piers. Its density and freedom from joints make waterproofing much easier and more effective. Its application in a plastic condition against a vertical excavation in hard ground gives an easy method of practically filling voids in the earth which, if left open, might cause future settlement of surrounding buildings. Without concrete, the caisson system of foundations would be scarcely possible.

While concrete is an admirable material in every way when it is all right, it has not become so well known that it can safely be used without caution. Unlike rolled steel, it is not manufactured by standard processes in mills doing nothing else, but it is put together on the ground in relatively small quantities and composed of whatever materials can be easily obtained. The selection of materials, especially the sand, is of great importance and requires watchful care at all times. It requires

supervision of a higher class than any other common material of construction.

Caisson Foundations.

The use of caissons has not been very extensive as yet in Boston, though they have been adopted in some instances, the foundations for the new Custom House tower being the most notable example. The old building was supported upon large-size, short, pointed piles which extended only a little way into the clay. The consequence was that on every occasion when the ground water was pumped to a low level in the vicinity, the clay contracted and the building settled. At the time the East Boston Tunnel was begun in State Street, it was found that the Custom House was out of level, the southerly side being two to three inches lower than the northerly or State Street side. The construction of the tunnel caused a settlement of the northerly side which brought all parts nearly to the same level. The weight of the new tower was considered too great to place on this kind of a foundation, and the architects decided to carry the support down to ledge or the hardpan immediately over it. To do this, it was determined to carry down concrete caissons by means of compressed air. Considerable difficulty was experienced in forcing the caissons down on account of the friction of the soil against the sides, even when the ground was completely excavated under the cutting edge, but it has been successfully accomplished and the caissons filled with concrete.

The sinking of the caissons under the central portion of the building produced further settlements of the original building in spite of the use of compressed air to control the water, but it is thought that no more trouble will be experienced now that the soil has come to rest.

Foundations resembling caissons but constructed in a different way have been used in many instances. Examples of these are in the Filene Building. Here cylinders twelve feet in diameter were sunk under each column. The excavations were sheathed with vertical plank supported by bent steel hoops on the inside. Compressed air was not used and no trouble was experienced with water except in a few places, though a

rather large pumping outfit was required when a number of foundations were going down at once.

A similar system has been used by Mr. Charles R. Gow in many places, where he has excavated holes about three feet in diameter within metal plate forms made so that they can be removed as the concrete is filled in. In many of these, where the ground permitted, the bottom of these holes has been enlarged in a conical form to increase the bearing area on the ground. Where the soil does not carry water freely, as, for instance, in silt or peat, with the bottom resting in clay, this procedure has been found very efficient and economical.

Pressure on Soil.

In the earlier paper certain assumptions were tentatively suggested for pressure on the soil, but no experimental evidence was offered to support the figures. In the discussion attention was called to the danger of reasoning from the supporting power of a limited area, on account of the increasing area of the supporting cone of soil below the loaded spot and the fact that with numerous adjoining loads the cones would interfere, thus preventing the rapid gain in area with increase of depth. There is also present in every test a condition having exactly the opposite tendency, which renders them unreliable. This is, that when a limited area is loaded, the soil has a chance to flow out in every direction and, as the area of the load increases, the opportunity for flow is relatively decreased. The first error, which would be liable to give too high capacities, is important in the case of a harder ground over a softer. The second, which may give too low results, is more likely to be found in the case of a soft plastic material, like clay, immediately under the loaded point.

It has been found difficult to prepare for a test of clay so as to apply the load to soil in its natural condition. The best way that the writer knows is to excavate a pit, large enough to work in, down to a level about one foot above the grade at which the load is to be applied. From the bottom of this excavation, a small pit is carefully dug by hand to the desired depth just the size of the plunger at the bottom and with a slight batter to the sides so as not to touch the plunger above the bottom. On the

top of the plunger a platform can be constructed to receive the load and this must be held firmly in horizontal position to allow no rocking motion. This can be done satisfactorily by means of boards laid horizontally and nailed to the platform and to stakes driven into the ground at the level of the platform.

It is to be regretted that there are not more tests on record, for, in spite of the allowances which must be made for misleading conditions, they furnish valuable information. The following table gives the results of the few which are accessible. It is hoped that more may be added in the discussion. The first three were made by the Boston Transit Commission at the bottom of the Washington Street Tunnel, and are reported in detail in Appendix J of the Eleventh Annual Report of the Commission, June 30, 1905. The last was a test of a foundation built by Chas. R. Gow & Co. for the Boston & Maine Railroad.

Except in the case of the last test these loads were applied to about one square foot of soil. The last was a caisson pile 3 ft. in diameter, enlarged at the bottom to 4 ft. in diameter. It was 12 ft. in depth. The soil upon which it rested consisted of about two thirds yellowish gray clay and one third very fine gray sand. This material in its natural state was plainly well saturated with moisture and in appearance was more sandy than its subsequent analysis proved it to be. The soil surrounding the upper portion of the pile was clay filling, quite wet, except for two feet of compressed silt just above the sandy clay. The settlement all took place within the first day after the load was applied.

The lesson to be drawn from these tests would seem to be that, even with light loads, clay that appears hard is likely to settle slightly in reaching a bearing, and that for additions to the load temporary increases in settlement may occur. It is probable that where larger areas are covered and the chance of escape of material laterally is reduced, these slight settlements are less noticeable. It appears that with "quite soft clay" it requires from $3\frac{1}{4}$ to 5 tons per sq. ft. to produce $\frac{1}{2}$ in. of settlement. With "rather soft clay" it requires from 5 to 10 tons to produce the same settlement. With "hard clay" 10 tons has also been found to produce this effect.

BEARING POWER OF SOIL.

Location.	Nature of Soil.	Load. Tons per Sq. Ft.	Settlement. Inches.	Time. Days.	Time. Hours.
Kneeland St.	Quite soft clay.	4.74	0.38–0.47	3	
		5.83	0.64–1.21	4	
		6.92	2.62–3.10	6	
		8.02	3.70–4.15	5	
		9.11	4.30–4.70	6	
Harvard St.	Rather soft clay.	2.60	0.02		1
		3.85	0.08		1
		5.24	0.12		1
		6.38	0.19		1
		7.52	0.32		1
		8.65	0.36		1
		9.79	0.44	1	
		10.96	0.59–0.67	1	
		12.12	0.74–1.26	23	
Bennet St.	Hard clay.	4.72	0.048–0.108	6	
		5.82	0.144–0.18	6	
		6.91	0.18 –0.288	6	
		8.00	0.288–0.36	6	
		9.23	0.36 –0.492	6	
		10.18	0.55 –0.74	10	
Milk and Hawley Sts. *A*	Quite soft clay.	2.75	0.31	7	
		3.75	0.34–0.38	2	
(Load removed and again applied.)		2.00	0.50	2	
		3.20	0.50–0.53	3	
		4.80	1.00	2	
		5.15	1.19	3	
Milk and Hawley Sts. *B*	Rather soft clay.	2.75	0.31	7	
		3.75	0.34	2	
(Load removed and again applied.)		2.00	0.40	2	
		3.20	0.40	3	
		4.80	0.47	2	
		5.15	0.53	3	

BEARING POWER OF SOIL. — *Continued.*

Location.	Nature of Soil.	Load. Tons per Sq. Ft.	Settlement. Inches.	Time. Days.	Time. Hours.
Milk and Hawley Sts. *C*	Rather soft clay.	2.75	0.25	7	
		3.75	0.28–0.31	2	
(Load removed and again applied.)		2.00	0.37	2	
		3.20	0.37–0.47	3	
		4.80	0.50	2	
		5.15	0.56	3	
Boston & Maine R. R., Charlestown.	Medium soft, sandy clay.	3.14	0.25	6	

These results would seem to show that the recommendations of the former paper, of from $2\frac{1}{2}$ to 4 tons as proper allowances, were conservative, and the same is indicated by the fact that no trouble has been experienced in very many buildings designed on this basis.

PILE TESTS.

A number of pile tests have been observed, the results of which are embodied in the following table. The first experiment in the table was that reported by the late Wm. Parker in his discussion of the 1903 paper; the second was conducted by the late Geo. B. Francis in connection with the construction of the South Station; and the ninth was made by the Sewer Department of the city, under Mr. E. S. Dorr. The last five, made for the Massachusetts Institute of Technology, were contributed by Mr. F. N. Bushnall, vice-president, Stone & Webster Engineering Corporation.

TESTS OF PILES.

Locality.	Length in Ground. Feet.	Tip Diameter. Inches.	Wt. Hammer. Lbs.	Fall of Hammer. Ft.	Penetration, last blow. Ins.	Test Load. Lbs.	Settlement. Inches.
1. B. & A. Warehouse, E. Boston,	40	6	2 050	20	1.92	60 000	0
2. South Station . .	27	. .	2 000	16	3 to 4	40 000	0
3. India St.	20 long; 7 in clay	6	1 900	22–23	3	41 740	0
4. Homœopathic Hospital, E. Concord St.	20	$6\frac{3}{4}$	1 800	15	2	20 000	0
						25 000	$\frac{1}{8}$
						30 000	$\frac{1}{8}$
						35 000	$\frac{1}{4}$
						40 000	$\frac{5}{16}$
NOTE: Loads were applied continuously. During test, another hammer was at work within 30 ft. of the test pile.						45 000	$\frac{7}{16}$
						50 000	$\frac{5}{8}$
						55 000	$\frac{7}{8}$
						60 000	$1\frac{3}{8}$
						65 000	$1\frac{3}{4}$
						70 000	$2\frac{3}{8}$
						75 000	$3\frac{5}{16}$
5. Do.	31	6	1 800	15	$2\frac{3}{4}$	20 000	0
						25 000	$\frac{1}{16}$
						30 000	$\frac{1}{8}$
						35 000	$\frac{1}{8}$
						40 000	$\frac{1}{8}$
						50 000	$\frac{1}{8}$
						60 000	$\frac{3}{16}$
						70 000	$\frac{1}{4}$
6. Wentworth Institute, Huntington Ave. and Ruggles St.	37	$5\frac{1}{2}$	2 000	20	6	2 000	0
						7 500	$\frac{1}{16}$
						12 500	$\frac{1}{8}$
						17 500	$\frac{3}{16}$
						22 500	$\frac{5}{16}$
						27 500	$\frac{3}{8}$
						32 500	$\frac{1}{2}$
						42 500	$\frac{1}{2}$
						48 000	$\frac{17}{32}$
						52 500	$\frac{3}{4}$

TESTS OF PILES. — *Continued.*

Locality.	Length in Ground. Feet.	Tip Diameter. Inches.	Wt. Hammer. Lbs.	Fall of Hammer. Ft.	Penetration, last blow. Ins.	Test Load. Lbs.	Settlement. Inches.
7. Sumner St., E. Boston.	11	$7\frac{1}{2}$	2 250	10	2	12 650	0
						26 900	$\frac{1}{8}$
						35 450	$\frac{3}{8}$
						44 000	$\frac{1}{2}$
8. Copley-Plaza Hotel, Copley Square.	30	6	2 300	17	3	77 000	$\frac{7}{16}$
9. Union Park and Albany Sts.	25	..	2 100	8.6	$3\frac{1}{2}$	10 860	$\frac{1}{16}$
						20 860	$\frac{3}{16}$
						30 860	$\frac{1}{4}$
						40 860	$\frac{5}{16}$
						50 860	$\frac{3}{8}$
						60 860	$\frac{11}{16}$
NOTE: The interval between last two observations was one day.						70 860	$1\frac{7}{8}$
						70 860	1 7
10. Cambridge. Site of new Mass. Inst. of Technology buildings.	28.7	$5\frac{1}{2}$	2 300	9	2	7 570	$\frac{5}{32}$
						12 710	$\frac{7}{32}$
						22 850	$\frac{9}{32}$
						28 140	$\frac{19}{64}$
						33 240	$\frac{27}{64}$
						48 480	$\frac{35}{64}$
						53 350	$\frac{5}{8}$
						58 330	$\frac{13}{16}$
						61 910	$\frac{31}{32}$
11. Do.	32.08	6	2 300	10	2	9 280	0
						15 150	$\frac{1}{16}$
						27 700	$\frac{1}{8}$
						46 210	$\frac{5}{32}$
						51 190	$\frac{7}{32}$
						56 480	$\frac{1}{4}$
						61 690	$\frac{5}{16}$
						2 300	$\frac{3}{32}$

TESTS OF PILES. — *Continued.*

Locality.	Length in Ground. Feet.	Tip Diameter. Inches.	Wt. Hammer. Lbs.	Fall of Hammer. Ft.	Penetration. last blow. Ins.	Test Load. Lbs.	Settlement. Inches.
12. Do.	41.6	$5\frac{1}{2}$	2 300	11	$1\frac{1}{2}$	9 020	$\frac{1}{8}$
						15 290	$\frac{1}{4}$
						20 010	$\frac{5}{16}$
						30 330	$\frac{13}{32}$
						56 970	$\frac{7}{16}$
						62 790	$\frac{15}{32}$
						68 000	$\frac{21}{32}$
						2 300	$\frac{15}{32}$
13. Do.	26.7	6	2 300	10.5	2	7 070	$\frac{1}{32}$
						18 080	$\frac{1}{16}$
						28 550	$\frac{3}{32}$
						34 010	$\frac{1}{8}$
						51 800	$\frac{3}{16}$
						58 070	$\frac{17}{64}$
						62 800	$\frac{7}{32}$
						2 300	$\frac{5}{32}$
14. Do.	23.6	6	2 300	6.3	$\frac{5}{8}$	11 000	$\frac{3}{64}$
						14 900	$\frac{5}{64}$
						20 400	$\frac{3}{32}$
						25 700	$\frac{1}{8}$
						30 670	$\frac{3}{16}$
						35 780	$\frac{1}{4}$
						40 350	$\frac{9}{32}$
						46 220	$\frac{13}{32}$
						54 580	$\frac{7}{16}$
						61 560	$\frac{17}{32}$
						2 300	$\frac{3}{16}$

CONCLUSIONS FROM PILE TESTS.

These tests are too few to warrant any very sweeping conclusions, but some interesting deductions may be drawn from them. In each case it will be observed that the ground was comparatively soft, that is, the piles were mainly supported by

"suction" or "friction," the end bearing not being much of a factor. In ten instances it appears that small settlements occurred under comparatively light loads and that succeeding increments of loads produced gradually increasing settlements. The writer is inclined to believe that more accurate observations of levels would have detected the same condition in the other tests, but of this we cannot be certain. If we assume that $\frac{1}{4}$-in. motion is allowable and that more would have been observed and recorded, we could condense the table into the following form.

Test No.	P.	W.	h.	p.	$\frac{Wh}{p+1}$	C.
1	60 000	2 050	20	1.92	14 000	4.3
2	40 000	2 000	16	3.5	7 100	5.6
3	41 740	1 900	22.5	3	10 700	3.9
4	35 000	1 800	15	2	9 000	3.9
5	70 000	1 800	15	2.75	7 200	9.7
6	20 000	2 000	20	6	5 700	3 5
7	30 000	2 250	10	2	7 500	4 0
8	44 000*	2 300	17	3	9 800	4 5
9	30 860	2 100	8.6	$3\frac{1}{2}$	4 000	7 7
10	22 850	2 300	9	2	6 900	3.3
11	56 480	2 300	10	2	7 670	7.4
12	15 290	2 300	11	$1\frac{1}{2}$	10 120	1.5
13	58 070	2 300	10.5	2	8 050	7.2
14	35 780	2 300	6.3	$\frac{5}{8}$	8 920	4.0

* Interpolated.

In this table, P = the load carried in pounds.
W = weight of hammer in pounds.
h = drop in feet.
p = penetration under last blow in inches.
C = coefficient which, applied to the formula $\frac{Wh}{p+1}$, will bring the theoretical capacity into agreement with the observed load, that is: $P = \frac{CWh}{p+1}$.

If we disregard No. 5, which developed unusual capacity, and 12, which settled $\frac{1}{4}$ in. at a light load but was afterwards all right, we find that the value of C appears to be nearly constant at about 4. The "*Engineering News* formula," so generally followed, is identical with this, with a value of 2 for C, for safe loads. It would appear from these tests that the formula is

in satisfactory shape for correlating varying elements, though it does not appear always to have a factor of safety of 6, as it is supposed to have. If we use it with the understanding that it gives a factor of safety of 2 as regards the load which may be expected to cause a settlement of $\frac{1}{4}$ in., it would seem to correspond quite closely with the experimental knowledge thus far attained.

Considering the same piles as sustaining their load by end bearing and by "friction" or "suction," the following table may be arranged. The area of pile is estimated on the assumption that the taper would increase the diameter 4 in. in 20 ft. Where the tip diameter is not known it is assumed as 6 in. and the end bearing is assumed at 5 tons per sq. ft.

No.	*P.* Lbs.	Tip Diameter. Ins.	Length. Ft.	End Bearing. Lbs.	Friction. Lbs.	Area. Sq. Ft.	Coefficient Lbs. per Sq. Ft.
1	60 000	6	40	1 980	58 020	104.8	553
2	40 000	6	27	1 980	38 020	61.3	620
3	41 740	6	20	1 980	39 760	41.8	950
4	35 000	$6\frac{3}{4}$	20	2 500	32 500	45.8	710
5	70 000	6	31	1 980	68 020	73.5	930
6	20 000	$5\frac{1}{2}$	37	1 660	18 340	89.4	205
7	30 000	$7\frac{1}{2}$	11	3 060	26 940	27.7	970
8	44 000	6	33	1 980	42 020	70.7	600
9	30 860	6	25	1 980	28 880	55.7	518
10	22 850	$5\frac{1}{2}$	28.7	1 660	21 190	62.8	338
11	56 480	6	32.08	1 980	54 500	77.0	706
12	15 290	$5\frac{1}{2}$	41.6	1 660	13 630	104.8	130
13	58 070	6	26.7	1 980	56 090	60.6	915
14	35 780	6	23.6	1 980	33 800	51.5	653

The variation in coefficients is not very great except in the case of No. 6 and No. 12. The reason that No. 6 is so low is that while the pile was long, the greater part of the length was driven through a silt which adds little to its carrying power. No. 12, as explained above, had a rapid penetration at first but brought up later. Disregarding these tests, the average coefficient is 628. If we use 300, we would have about the same factor of safety as with the *Engineering News* formula and apparently about equally consistent results. It is well to note, however, that it is not always safe to take into account the portion of

the pile which is embedded in an inferior material, and the objection to the use of this method is the uncertainty as to how much length to consider.

Summary of Recommendations.

In conclusion it may be well to summarize the recommendations based on the foregoing data and arguments.

1. In designing foundations, preliminary borings are of great value to assist in determining: (*a*) At what level, if at all, firm soil may be reached; (*b*) whether piles are likely to be an advantage, and if so, about how long they will probably be; (*c*) in case a hard crust is encountered, its thickness, and the nature of the underlying material.

2. It is of great importance to support all parts of structures on a stratum of soil below the silt and peat.

3. The maximum and minimum levels of the ground water should be determined. The maximum to obtain the hydrostatic head on waterproofed basements and the minimum to determine a safe level for cutting wooden piles. Subject to review in case the discussion should prove inaccuracy, the writer suggests grade 12.00* for the higher and grade 8.00* for the lower limit.

4. As tentative suggestions for safe bearing pressures on soil, the writer proposes the following:

Dry, hard, yellow clay, "bowlder clay," dry sand or gravel	6 tons per sq. ft.
Compact, damp sand, hard sandy clay, hard blue clay	5 tons per sq. ft.
Medium blue clay, whether or not mixed with fine sand	$3\frac{1}{2}$ tons per sq. ft.
Soft clay, running sand (confined)	$2\frac{1}{2}$ tons per sq. ft.

5. For the safe supporting power of piles, the formula $P = \frac{3Wh}{p+1}$ (*Engineering News* formula + 50 per cent.).

P = supporting power in pounds.
W = weight of hammer in pounds.
h = fall of hammer in feet.
p = penetration in inches.

* Referred to Boston City Base.

If these recommendations are freely criticised by those who are kind enough to discuss the paper, it is hoped that we may reach conclusions which will unify local practice and produce beneficial results.

APPENDIX.

In this appendix will be found the following maps:

1. Boston Peninsular.
2. South Boston.
3. South Cove District.
4. Back Bay and Roxbury.
5. Brookline.
6. Harvard Square District.
7. East Cambridge.
8. Charlestown.
9. East Boston and Chelsea.

On these maps, besides the present shore line and the streets, will be found the original shore line shown by heavy broken lines and the locations of the borings, shown by black circles, each with a number. The numbers begin with 1 on each map, so that in following out the references it is necessary to keep constantly in mind the map on which the number is found.

The maps are not prepared with special accuracy as they are intended only for the purpose of indicating the approximate locations of the borings, and no claim is made as to the correctness of the location of the original shore line. It is thought, however, that it is near enough to serve as a guide in studying the nature of the ground.

It is a source of regret that no more convenient way has been found for reproducing the borings. It is necessary, after locating a boring by number on the map, to consult the profile sheet on which it is illustrated and then to look up in the table giving the soil formations the meaning of the numbers in the diagram. No set of abbreviations for the materials could give the full shade of meaning conveyed by the words without being so cumbersome as to require a key similar to that here employed, and room could not be found on the maps to insert more than a reference number. A slight help in a general interpretation of the profiles will be found in the grouping of neighboring borings and in the use of similar numbers for similar formations. The

principal liberty which has been taken in the transcription of the reports of borings has been in classifying together all filling material. This has been done on account of the relative unimportance of fill, upon which foundations should never depend.

In order to decrease the number of classifications, other slight changes have been made which could not affect the sense, such as the substitution of "clay and sand" for "sand and clay." These changes are, however, rare, and no doubt many separate numbers are assigned for materials which may be identical.

In most cases the profiles show elevations referred to Boston Base, 0.64 ft. below mean low water, but in some instances, where the grade could not be learned, the depths below the surface of the ground are substituted for the actual elevations.

The author is indebted to many gentlemen for their assistance in supplying the data from which these maps and profiles have been prepared. Acknowledgment is due to the Public Works Department of the City of Boston, through Mr. F. H. Fay, division engineer; to the Boston Transit Commission, through Mr. E. S. Davis, chief engineer, and Mr. G. H. Stearns, assistant engineer; to the Metropolitan Park Commission, through Mr. John R. Rablin, chief engineer; to the Metropolitan Water and Sewerage Board, through Mr. F. D. Smith, chief engineer of sewerage works; to the Directors of the Port of Boston, through Mr. F. W. Hodgdon, chief engineer, and Mr. R. E. Barrett, designing engineer; to the Boston Elevated Railway, through Mr. C. T. Fernald, assistant engineer; and to many others, but especially to Mr. Charles R. Gow and Mr. Henry F. Bryant, who furnished all their boring records and devoted much attention to making them available. The author also wishes to express his obligation to his partners, Mr. E. E. Pettee and Mr. G. H. Brazer, for their cordial coöperation and valuable suggestions.

SOIL FORMATIONS.

NOTE. — The following table gives the explanation of the numbers shown on the profile sheets. The principal ingredient of any combination is indicated by the hundreds figure of the number. For this reason the table is not in complete numerical sequence, the thousands figure being used only for the purpose of extending the groups containing more than 100 varieties.

Clay or Blue Clay Combinations.

100. Soft blue clay or soft clay.
101. Soft wet blue clay.
102. Hard blue clay.
103. Hard wet blue clay.
104. Blue clay, yellow clay, sand, hard.
105. Fine clay, sand.
106. Clay, fine sand, wet.
107. Clay, fine blue sand, wet.
108. Clay, fine yellow sand.
109. Clay, sand.
110. Clay, fine sand.
111. Hard blue clay, little sand.
112. Hard blue clay, fine sand.
113. Hard blue clay, little fine sand.
114. Hard clay, gravel.
115. Hard blue clay, fine gravel.
116. Blue clay, fine sand, gravel.
117. Hard blue clay, sand, gravel.
118. Clay, sand, coarse gravel.
119. Clay, sand, gravel, hard.
120. Clay, coarse sand, gravel, hard.
121. Little clay, sand, coarse gravel.
122. Hard, blue clay, sand, fine gravel.
123. Clay, sand, gravel, mud.
124. Clay, sand, gravel, stones, hard.
125. Clay, sand, stones.
126. Clay, sand, stones, hard.
127. Clay, sand, little stones.
128. Clay, little sand, stones.
129. Clay, sand, shells.
130. Clay, gravel, stones, hard.
131. Clay, mud, stones, hard.
132. Hard clay, stones.
133. Clay, gravel.
134. Blue clay, stones.
135. Hard blue clay, sand.
136. Hard clay, little sand, stones.
137. Hard clay, fine stones.
138. Clay, silty sand, gravel.
139. Clay, sandy gravel.
140. Blue clay or clay.
141. Clay, mud, stones.
142. Fine clay, mud, stones, hard.
143. Hard blue clay, little gravel.
144. Little clay, sand, gravel, soft.
145. Blue clay, fine sand.
146. Clay, fine sand, fine gravel.
147. Blue clay, sand, gravel, stone.
148. Soft blue clay, sand.
149. Soft blue clay, little sand.
150. Hard blue clay.
151. Little clay, fine blue sand.
152. Little coarse, hard fine sand, gravel.
153. Hard blue clay, sand, little gravel.
154. Clay, coarse sand, gravel.
155. Clay, mud.
156. Clay, gravel, mud.
157. Little clay, silt.
158. Hard blue clay, little sand, gravel.
159. Soft clay, mud.
160. Soft clay, gravel.
161. Clay, fine brown sand.
162. Clay, black mud.
163. Clay, hard gravel.
164. Clay, yellow sand, stones.
165. Clay, yellow gravel.
166. Clay, sand, coarse gravel, hard.
167. Hard clay, coarse sand.
168. Little clay, sand.
169. Clay, little sand.
170. Silty clay, sand, shells.
171. Blue clay, little fine sand.
172. Hard blue clay, little sand, little gravel.
173. Little clay, sand, silt.
174. Little clay, sand, gravel.
175. Little clay, sand, little gravel.
176. Little clay, blue sand.
177. Clay, blue sand.
178. Little clay, fine sand.
179. Clay, fine blue sand.
180. Hard clay, little sand, little gravel.
181. Clay, coarse sand.
182. Clay, sand, gravel, shells.
183. Blue clay, coarse gravel.
184. Clay, hard blue sand, gravel.
185. Little clay, sand, gravel, hard.
186. Clay, gravel, stones.
187. Clay, little gravel.
188. Little clay, gravel.
189. Clay, brown sand.
190. Little clay, blue sand, gravel.
191. Hard blue clay, coarse gravel.
192. Clay, yellow sand.
193. Fine blue clay, sand.

194. Clay, brown sand, gravel, hard.
195. Coarse brown clay, sand, gravel, hard.
196. Blue clay, sand, coarse gravel, hard.
197. Clay, sand, fine gravel.
198. Clay, sand, gravel, wet.
199. Little clay, fine yellow sand, silt.
1101. Stiff or tough blue clay or stiff clay.
1102. Fairly or medium stiff blue clay.
1103. Clay, sand and gravel.
1104. Blue clay, little gravel, very fine sand.
1105. Very stiff blue clay.
1106. Stiff blue clay, little sand.
1107. Clay, little sand and coarse gravel.
1108. Stiff blue clay, little gravel.
1109. Clay, gravel and sand, very hard.
1110. Fairly stiff blue clay, little sand and gravel.
1111. Clay, blue sand and gravel.
1112. Stiff blue clay, little sand and gravel.
1113. Stiff blue clay, sand and little gravel.
1114. Clay, loose blue sand.
1115. Fairly stiff blue clay and gravel.
1116. Fairly stiff blue clay and fine sand.
1117. Soft clay and sand.
1118. Little stiff clay and sand.
1119. Blue clay, sand and gravel.
1120. Stiff blue clay, sand and gravel, very hard.
1121. Very hard clay, little sand.
1122. Stiff blue clay, fine sand.
1123. Clay, sand, gravel, wet.
1124. Hard clay.
1125. Clay, stones, streaks of sand
1126. Clay, stones.
1127. Blue clay, sand, soft.
1128. Clay, stones, hard.
1129. Blue clay, sand, stones.
1130. Stiff blue clay, stones.
1131. Stiff blue clay, sand, stones, hard.
1132. Stiff blue clay, stones, hard.
1133. Soft blue clay, stones.
1134. Blue silty clay, gravel.
1135. Clay, sand, gravel.
1136. Blue clay or clay, little sand.
1137. Stiff blue clay, little yellow sand.
1138. Stiff blue clay, little coarse sand.
1139. Blue clay, little blue sand.
1140. Plastic blue clay.
1141. Blue clay, little coarse sand.
1142. Plastic clay, some stones.
1143. Plastic blue clay, sand, stones.
1144. Blue clay, coarse sand, little gravel.
1145. Firm clay, gravel, sand.
1146. Clay, sand, little gravel.
1147. Clay, little sand, little gravel.
1148. Sandy clay.
1149. Soft blue clay, some peat.
1150. Fairly soft blue clay.
1151. Clay, gravel, bowlders.
1152. Soft blue clay, some gravel.
1153. Sandy clay, gravel.
1154. Fairly hard blue clay.
1155. Stiff blue clay, little sand. peat.
1156. Blue clay, little peat, silt.
1157. Silty clay, little fine sand.
1158. Bowlder clay.
1159. Clay, sand, gravel and stones, hard.
1160. Stiff blue clay, little fine sand.
1161. Clay, little sand, very hard.
1162. Clay, gravel, very hard.
1163. Stiff blue clay, little sand, fine gravel.
1164. Blue clay, sand.
1165. Blue clay, sand, bowlder.
1166. Hard clay, little fine sand.
1167. Hard clay, sand, gravel.
1168. Hard clay, coarse gravel, sand.
1169. Stiff blue clay, sand.
1170. Hard blue clay, sand, gravel.
1171. Hard dry blue clay, sand, gravel.
1172. Hard dry blue clay, sand, coarse gravel.
1173. Clay, sand, gravel, bowlders.
1174. Hard blue clay and yellow clay.
1175. Medium soft blue clay, little sand.
1176. Soft clay, little gravel.
1177. Stiff clay, little sand.
1178. Hard clay, sand and much gravel.
1179. Stiff blue clay, coarse gravel, little sand.
1180. Soft blue clay, very little fine sand.
1181. Blue clay, sand, little gravel.
1182. Hard blue clay, little sand and coarse gravel.
1183. Fairly stiff blue clay, sand and little gravel.
1184. Fairly stiff blue clay, sand and gravel.
1185. Indurated clay.
1186. Blue and yellow clay.
1187. Firm blue sandy clay.
1188. Fairly firm blue clay, little sand.
1189. Fairly stiff blue clay, some sand, coarse gravel.
1190. Stiff, dry blue clay, sand and gravel.
1191. Blue clay, gravel and shells.
1192. Stiff blue clay, gravel.
1193. Soft sandy blue clay, some gravel.
1194. Soft blue clay, shells.
1195. Soft dark clay.
1196. Stiff blue sandy clay, gravel.
1197. Clay, gravel, wet.
1198. Clay, sand, wet.
1199. Dry blue clay.
2100. Wet blue clay.
2101. Fine silty blue clay.
2102. Stiff blue clay, yellow sand.

2103. Blue clay, streaks of yellow sand.
2104. Blue clay, little sand and gravel.
2105. Stiff blue clay, little sand, angular stones.
2106. Blue clay, some peat.
2107. Little blue clay, fine gray sand.
2108. Hard dry clay, bowlders.
2109. Stiff blue clay, little peat.

Yellow Clay Combinations.

200. Soft yellow clay.
201. Hard yellow clay.
202. Hard yellow clay, wet.
203. Hard yellow clay, sand.
204. Hard yellow clay, fine sand.
205. Hard yellow clay, little fine sand.
206. Hard yellow clay, sand, gravel.
207. Hard yellow clay, sand, blue gravel.
208. Hard yellow clay, fine sand, gravel.
209. Yellow clay, sand, gravel.
210. Hard yellow clay, sand, gravel, stones.
211. Hard yellow clay, sand, gravel, shells.
212. Yellow clay, sand, gravel, hard.
213. Yellow clay, gravel, hard.
214. Yellow clay, gravel.
215. Yellow clay, sand.
216. Yellow clay, fine sand.
217. Hard yellow clay, fine sand.
218. Yellow clay, sand, coarse gravel.
219. Hard yellow clay, little sand.
220. Soft yellow clay, sand.
221. Soft yellow clay, sand, gravel.
222. Yellow clay, stones.
223. Yellow clay, gravel, stones.
224. Yellow clay, little sand, stones.
225. Coarse yellow clay, hard.
226. Hard yellow clay, sand, coarse gravel.
227. Yellow clay, sand, stones.
228. Yellow clay, sand, little gravel.
229. Hard yellow clay, little gravel.
230. Yellow clay.
231. Yellow clay, little sand.
232. Stiff yellow clay.
233. Yellow clay, sand, gravel, stones.
234. Stiff yellow clay, little gravel.
235. Fairly stiff yellow clay, little sand and gravel.
236. Fairly stiff yellow clay, little sand.
237. Stiff yellow clay, little fine sand.
238. Yellow clay, little gravel.
239. Fairly stiff yellow clay.
240. Stiff yellow clay, little sand.
241. Stiff yellow clay, stones.
242. Stiff yellow clay, stones, hard.
243. Stiff yellow clay, sand and gravel.
244. Very hard yellow clay, sand and gravel.
245. Bluish yellow clay, fine sand, little fine gravel, stiff.
246. Yellow clay, sand and fine gravel.
247. Yellow clay and fine gravel.
248. Yellow clay, little fine sand.
249. Stiff yellow clay mottled with blue.
250. Sandy yellow clay.
251. Yellow clay, gravel, sand.
252. Stiff yellow clay, fine gravel.
253. Yellow clay, sand, fine gravel.
254. Yellow and blue clay, coarse gravel, little sand.
255. Yellow clay, coarse sand.
256. Fine yellow clay, little sand.
257. Stiff dry yellow clay, sand, gravel.
258. Stiff yellow clay, sand.
259. Yellow clay, hard pan, brown sand.
260. Stiff yellow clay, little yellow sand.
261. Stiff dry yellow clay, little sand.
262. Yellow clay, little sand, very little gravel.
263. Stiff yellow clay, fine sand.
264. Yellow and blue clay, mixed.
265. Yellow clay, sand, little gravel.

Sand Combinations.

300. Sand.
301. Brown sand.
302. Coarse sand.
303. Coarse wet sand.
304. Wet sand.
305. Fine sand.
306. Fine wet sand.
307. Fine yellow sand.
308. Fine blue sand.
309. Fine wet blue sand.
310. Fine sharp sand.
311. Fine sharp wet sand.
312. Sharp yellow sand.
313. Sand, gravel.
314. Sand, gravel, wet.
315. Fine sand, gravel.
316. Fine sand, gravel, wet.
317. Coarse sand, gravel.
318. Coarse sand, gravel, wet.
319. Sand, gravel, hard.
320. Sand, gravel, coarse, hard.
321. Coarse sand, fine gravel.
322. Fine sand, fine gravel.
323. Fine yellow sand, fine gravel.
324. Coarse sand, fine gravel, black silt.
325. Silty sand, gravel.
326. Fine silty sand, fine gravel.
327. Sand, gravel, silt.
328. Sand, gravel, silt, mud.
329. Sand, gravel, silt, mud, shells.

330. Sand, fine gravel, silt, shells.
331. Sand, gravel, mud.
332. Sand, gravel, black mud.
333. Sand, gravel, stones.
334. Sand, gravel, stones, hard.
335. Coarse sand, fine gravel, shells.
336. Fine sand, silt.
337. Fine yellow sand, silt.
338. Black sand, silt.
339. Fine silty sand.
340. Soft fine silty sand.
341. Fine silty sand, mud.
342. Sand, silt, mud.
343. Sand, silt, blue mud.
344. Fine sand, silt, mud, shells.
345. Black sand, silt, mud, shells.
346. Silty sand, shells.
347. Fine silty sand, shells.
348. Soft fine silty sand, shells.
349. Fine sand, silt, shells.
350. Fine sand, blue silt, shells.
351. Fine muddy sand.
352. Sand, mud.
353. Yellow sand, mud.
354. Brown sand, mud.
355. Coarse sand, mud.
356. Sand, mud, shells.
357. Fine sand, shells.
358. Soft wet sand, shells.
359. Yellow sand, stone, wet.
360. Yellow sand, fine stones.
361. Silty sand.
362. Yellow sand.
363. Coarse sand, gravel, hard.
364. Fine sand, hard.
365. Fine sand, gravel, hard.
366. Blue sand, gravel.
367. Hard silty sand.
368. Soft silty sand.
369. Hard blue sand, gravel.
370. Little sand, silt.
371. Fine sand, mud.
372. Little sand, hard silt.
373. Silty sand, mud, shells.
374. Silty sand, little mud, shells.
375. Sand, mud, stones.
376. Sharp wet sand, shells.
377. Sand, coarse gravel.
378. Silty sand, gravel, hard.
379. Sharp yellow sand, little gravel.
380. Yellow sand, little gravel.
381. Coarse sand, little gravel.
382. Coarse sand, gravel, shells.
383. Sand, gravel, timber.
384. Fine sand, silt, shells, piles.
385. Sand, fine silt, shells.
386. Sand, gravel, shells.
387. Coarse blue sand.
388. Coarse brown sand.
389. Blue sand.
390. Sand, stones.
391. Sand, little stones.
392. Yellow sand, gravel.
393. Yellow sand, stones.
394. Sand, coarse yellow gravel.
395. Sand, stones.
396. Coarse yellow sand.
397. Fine hard yellow sand.
398. Fine brown and blue sand.
399. Hard fine blue sand.
1300. Coarse sand and peat.
1301. Soft sand and gravel.
1302. Sand, gravel, little clay, fairly hard.
1303. Sand and little gravel.
1304. Sand, gravel, very little clay.
1305. Sand and gravel, loose.
1306. Sand, little gravel, loose.
1307. Firm sand and clay, very fine.
1308. Fine sand, clay, little gravel, hard.
1309. Blue sand, coarse gravel, little clay.
1310. Sand, very little gravel.
1311. Coarse silty sand.
1312. Blue sand, coarse gravel.
1313. Blue sand, coarse gravel, very little clay.
1314. Yellow sand, coarse gravel, very little clay.
1315. Yellow sand, little clay.
1316. Gray sand.
1317. Fine sand, little gravel.
1318. Soft sand.
1319. Hard yellow sand, gravel, stones, little clay.
1320. Sand, gravel, very little clay, very hard.
1321. Blue sand, very little gravel.
1322. Yellow sand, little clay, gravel.
1323. Sand, little gravel and blue clay.
1324. Fine sand, little clay, soft.
1325. Sand, gravel, little clay, soft.
1326. Hard yellow sand, gravel, little clay.
1327. Sand, gravel, little clay.
1328. Loose sand, gravel, very little clay, soft.
1329. Sand, coarse gravel, little clay, fairly hard.
1330. Coarse sand, very little clay.
1331. Fine sand, little yellow clay.
1332. Fine soft sand, little gravel, wet.
1333. Fine sand, little clay, wet.
1334. Sand, little clay.
1335. Sand, clay, stones, hard.
1336. Sand, clay.
1337. Sand, clay, gravel.

1338. Fine sand, little clay.
1339. Gray sand, little clay.
1340. Sand, stones, clay, hard.
1341. Fine yellow sand, little clay.
1342. Fine white sand, little clay.
1343. Gray sand, stones.
1344. Sand, stones, hard.
1345. Sand, gravel, clay, hard.
1346. Sand, stones, little clay, hard.
1347. Sand, gravel and clay, stiff.
1348. Black sand and gravel.
1349. Sand and black silt.
1350. Quick sand.
1351. Fine brown sand.
1352. Fine brown sand, gravel.
1353. Coarse blue sand, little gravel.
1354. Fine blue sand, little gravel.
1355. Sand, little gravel.
1356. Silty sand, gravel.
1357. Coarse yellow sand.
1358. Fine blue sand, clay.
1359. Sand, little gravel, clay.
1360. Yellow sand, clay.
1361. Compact sand, fine gravel.
1362. Fine silty sand, clay, soft.
1363. Soft black silty sand.
1364. Compact sand.
1365. Fine sand, little clay, stiff.
1366. Fine blue sand, little clay.
1367. Fine blue sand, little clay, stiff.
1368. Hard fine sand, clay, gravel.
1369. Fine sand, little gravel, hard.
1370. Stiff blue sand, clay.
1371. Fine blue sand, little clay, soft.
1372. Fine sand, some peat, fairly hard.
1373. Fine sand, silt, fairly hard.
1374. Fine black sand.
1375. Firm gray sand.
1376. Brown sand, little gravel.
1377. Firm gray sand, little gravel.
1378. Blue and yellow sand, clay.
1379. Firm yellow sand, little clay.
1380. Hard sand, little gravel.
1381. Hard sand, little clay.
1382. Loose sand, clay.
1383. Blue sand, clay.
1384. Sand, silt.
1385. Fine stiff sand, some gravel.
1386. Fine clayey sand.
1387. Fine sand, some mud, stones.
1388. Coarse sharp sand.
1389. Sand, shells, gravel, little clay.
1390. Sand, fine gravel.
1391. Wet sand, fine gravel.
1392. Sand, coarse gravel, little clay.
1393. Sand, shells, little gravel.
1394. Sand, little silt.
1395. Silty sand, little gravel.
1396. Red sand.
1397. Fine gray sand, little clay.
1398. White sand.
1399. Fine white sand.
2300. Fine gray sand.
2301. Running sand.
2302. Fine sharp gray sand.
2303. Sand, gravel, bowlders.
2304. Sand, clay, peat.
2305. Hard sand, gravel, stone.
2306. Bluish gray sand, clay.
2307. Sand, gravel, clay, bowlders.
2308. Coarse silty sand, some gravel.
2309. Loose beach sand.
2310. Coarse sand, gravel, little clay.
2311. Blue sand.
2312. Loose wet sand, gravel.
2313. Fine sand, clay.
2314. Fine sand, little gravel, clay.
2315. Hard blue sand, little clay.
2316. Yellow sand, clay.
2317. Fine dry hard sand.
2318. Coarse sand, little gravel, little clay.
2319. Sand, gravel, clay and stones, hard.
2320. Sand, gravel, black silt.
2321. Coarse sand, gravel, little clay.
2322. Sand, gravel, yellow clay.
2323. Fine brown sand, little clay.
2324. Sand, gravel, blue clay, little yellow clay.
2325. Yellow sand, clay, gravel.
2326. Sand, gravel, streaks of blue clay.
2327. Fine brown sand, little brown clay.
2328. Fine gray sand, little clay.
2329. Brown sand, loose gravel.
2330. Sand, gravel, yellow clay, hard.
2331. Silty sand, bowlders.
2332. Coarse sharp sand and a little gravel.
2333. Silty sand, soft.
2334. Dark sand.
2335. Blue sand, clay, hard.
2336. Hard fine white sand.
2337. Hard granite sand.
2338. Hard yellow sand, little clay, little gravel.
2339. Loose sand, gravel and little clay.
2340. Hard sand, coarse gravel, little clay.
2341. Sand, coarse gravel, clay.
2342. Black silty sand.
2343. Hard sand, little gravel and little clay.
2344. Blue sand, little gravel and very little clay.
2345. Hard blue sand, coarse gravel and clay.
2346. Sand, peat, loam.
2347. White sand and clay.
2348. Sand, peat and gravel.

2349. Blue sand, gravel, little clay.
2350. Hard blue sand, little gravel, little clay.
2351. Coarse blue sand, coarse gravel, clay.
2352. Fine gray sand, little gravel.
2353. Fairly hard sand, little gravel, little clay.
2354. Fine sand, little clay and gravel.
2355. Sand, little gravel and little clay.
2356. Coarse silty sand and gravel (loose).
2357. Medium coarse sand, little gravel.
2358. Hard silty sand, gravel.
2359. Loose silty sand, gravel.
2360. Hard fine sand, little silt.
2361. Loose sand, gravel.
2362. Coarse sand, little silt.
2363. Fine firm blue sand and clay.
2364. Soft sand, clay.
2365. Fine soft sand, water.
2366. Fine sharp sand, little clay.
2367. Coarse sand, clay.
2368. Fine silty sand, stones.
2369. Fine silty sand, gravel.
2370. Sharp black sand, fine.
2371. Sharp black sand, coarse.
2372. Sharp black sand, coarse.
2373. Silty sand, gravel, loose.
2374. Yellow and blue sand.
2375. Coarse white sand.
2376. Fine silty sand, hard gravel.
2377. Fine silty sand, hard gravel, loose.
2378. Fine silty sand, hard gravel, hard.
2379. Fine silty sand, soft.
2380. Hard sand, gravel, loose.
2381. Fine yellow sand.
2382. Loose sand, little gravel.
2383. Loose sand, little gravel, little clay.
2384. Fine running sand.
2385. Loose coarse sand.
2386. Coarse silty sand, little gravel.
2387. Silty sand, peat.
2388. Silty sand, some gravel, shells.
2389. Silty sand, shells, gravel.
2390. Silty sand, shells, coarse gravel.
2391. Sand and shells.
2392. Fine silty sand and shells.
2393. Hard, dry, compact sand.
2394. Sand, little clay, old timber.
2395. Loose sand, gravel and clay.
2396. Firm fine sand, little clay.
2397. Coarse sand and gravel, slate pebbles.
2398. Coarse green sand and clay.
2399. Fine green sand.
3300. Fine sand and soft clay.
3301. Green sand, gravel, slate pebbles.
3302. Green sand, gravel.
3303. Coarse sand, gravel and clay, hard.
3304. Fine sand and slate pebbles.
3305. Green sand, clay, slate.
3306. Coarse brown sand, gravel.
3307. Green sand, indurated clay.
3308. Green sand, indurated clay, slate pebbles.
3309. Green sand.
3310. Green sand, clay.
3311. Green sand, slate pebbles.
3312. Coarse black sand.
3313. Sand, coarse gravel.
3314. Hard sand and gravel, little clay.
3315. Hard sand, clay, little gravel.
3316. Fine sand, much clay, hard.
3317. Sharp black fine sand, little clay.
3318. Sand, clay, gravel.
3319. Coarse gray sand.
3320. Gray running sand.
3321. Coarse gray sand, some clay.
3322. Coarse gray sand, some clay.
3323. Gray sand, little blue clay, wet.

Gravel Combinations.

400. Gravel.
401. Soft gravel.
402. Fine gravel.
403. Hard gravel.
404. Fine blue gravel.
405. Fine wet gravel.
406. Coarse gravel.
407. Black gravel, mud.
408. Black gravel.
409. Gravel, mud.
410. Gravel, shells.
411. Gravel, shells, mud, stones.
412. Gravel, shells, mud.
413. Yellow gravel.
414. Coarse gravel, little sand.
415. Dry gravel filling.
416. Compact dry gravel.
417. Loose wet gravel.
418. Very hard gravel.
419. Dry gravel.
420. Gravel, stones, hard.
421. Gravel, stones.
422. Gravel, sand.
423. Gravel, clay, stones, hard.
424. Gravel, clay, stones.
425. Clayey gravel and sand.
426. Clayey gravel.
427. Gravel, clay, hard.
428. Coarse gravel, clay and little mud.
429. Coarse gravel, sand.
430. Gravel, coarse sand.
431. Hard gravel, little clay.
432. Some gravel, clay.
433. Clayey gravel, yellow.

434. Wet gravel.
435. Coarse gravel, some clay.
436. Gravel, small bowlders.
437. Compact gravel, little sand and clay.
438. Coarse gravel, hard.
439. Gravel and clay, hard.
440. Gravel, little clay.
441. Gravel, clay, bowlders.
442. Gravel, little sand, clay.
443. Gravel, clay.
444. Gravel, little yellow clay.
445. Gravel, yellow clay.
446. Coarse gravel, blue clay.
447. Gravel, sand, brown clay.
448. Gravel, sand, blue clay.
449. Gravel, clay, loam, stones.
450. Fine gravel, sand.
451. Gravel, sand, stone.
452. Blue gravel.
453. Blue gravel, hard gravel.
454. Yellow gravel, clay.
455. Coarse blue gravel.
456. Gravel, ashes.
457. Gravel, peat, sand.
458. Coarse silty gravel.
459. Hard silty gravel.
460. Soft silty gravel.
461. Fine and coarse gravel, sand.
462. Gravel, sand, little silt.
463. Coarse gravel, blue sand, little clay.
464. Wet sandy gravel, little clay.
465. Loose gravel, sand.
466. Coarse gravel, sand, stone.

Silt Combinations.

500. Silt.
501. Soft black silt.
502. Hard black silt.
503. Hard blue silt.
504. Blue silt, mud.
505. Brown silt, mud.
506. Silt, mud, shells.
507. Silt, shells.
508. Hard blue silt, shells.
509. Black silt.
510. Soft silt, shells.
511. Silt, mud.
512. Brown silt, hard.
513. Soft sandy silt.
514. Sandy silt.
515. Soft black sandy silt.
516. Silty sand, coarse gravel.
517. Sharp silty sand.
518. Black silt, little sand and gravel, very soft.
519. Fairly stiff silt.
520. Stiff silty sand.
521. Silt and soft clay.
522. Silty clay.
523. Soft silty sand and gravel.
524. Soft silt.
525. Silt, little gravel.
526. Stiff silt.
527. Soft silty sand, shells.
528. Soft silt, sand, clay.
529. Black silt, sand, gravel.
530. Soft silt and sand.
531. Soft silt and little fine sand.
532. Silt, little clay.
533. Soft silt, sand, peat.
534. Silt, little fine sand.
535. Silt, little sand.
536. Silt, little coarse sand.
537. Silt, sand, little gravel.
538. Silt, sand.
539. Silt, fine sand.
540. Soft silt, little sand.
541. Silt, sand, gravel.
542. Silt, little sand, little gravel.
543. Silt, clay.
544. Silt, sand, little peat.
545. Stiff black silt.
546. Silt, sand, shells.
547. Shells.
548. Soft silt, little gravel.
549. Silt, little gravel.
550. Silt, some shells, little sand.
551. Black silt, little sand.
552. Black silt and little gravel.
553. Stiff silt, little peat.
554. Silt, shells, little sand.
555. Silt, little peat, little fine sand.
556. Soft silt, little sand and peat.
557. Silt, little sand, peat.
558. Silt, few shells.
559. Silt, sand, mud and gravel.

Mud Combinations.

600. Mud.
601. Black mud.
602. Brown mud.
603. Mud, shells.
604. Soft brown mud.
605. Hard mud.
606. Soft black mud.
607. Peat.
608. Silty peat.
609. Sandy peat.
610. Little peat, fine sand.
611. Little peat, soft silt and sand.
612. Peat, very fine sand.
613. Peat, soft silty sand.

614. Little peat, silt.
615. Coarse silty sand, soft mud.
616. Little peat, sand, gravel, firm.
617. Little peat, silty sand.
618. Peat, mud.
619. Soft black peat.
620. Little peat, silty sand, grave .
621. Little peat, silt, shells.
622. Peaty black silt.
623. Peat, little gravel.
624. Mud, stones.
625. Soft mud.
626. Loam.
627. Brown silty peat.
628. Soft silty peat.
629. Soft brown peat.
630. Peaty blue clay.
631. Black peat.
632. Blue silty peat, roots.
633. Light colored mud.
634. Sandy loam.
635. Sand, little peat.
636. Peaty sand, little gravel.
637. Peat and shells.
638. Silt, peat.
639. Soft mud, fine sand.
640. Soft mud, sand, some clay.
641. Bog mud with tendency to clay.
642. Black mud, fine sand.
643. Black mud, tendency to clay.
644. Loam, peat.
645. Loam, clay.
646. Soft peat.
647. Black mud, yellow sand.
648. Mud, gravel.
649. Peat, silt, stones.
650. Peat, silt, shells.
651. Peat, clay.
652. Silty peat, little fine sand.
653. Soft dark mud.
654. Mud, shells, sand.
655. Mud, sand.
656. Brown clay, mud.
657. Peaty clay, mud.
658. Peat, sand.
659. Loam, fine sand.
660. Silty peat, little sand.
661. Silty peat, fine sand.
662. Mud, loam.
663. Stiff silty peat.
664. Silty peat, sand.
665. Soft silty peat and sand.
666. Loam and hard gravel.
667. Peat, little fine sand.

Stone or Rock Combinations.

700. Stone.
701. Blue stone.
702. Ledge.
703. Rock.
704. Rocks.
705. Soft stone.
706. Bowlder.
707. Ledge or bowlder.
708. Concrete, stones.
709. Macadam.
710. Bowlders, gravel, clay.
711. Concrete.
712. Brick.
713. Paving.
714. Soft slate.
715. Arkose.
716. Soft altered green slate.
717. Decomposed ledge.
718. Slate ledge.
719. Slate.
720. Soft black slate.
721. Stone, gravel, sand, clay, hard.

Filling Combinations.

800. Filling.
801. Filling, wet.
802. Sand and gravel filling.
803. Yellow clay filling.
804. Coal dust and wood filling.

Hard Pan and Wood.

900. Hard Pan.
1000. Wood.

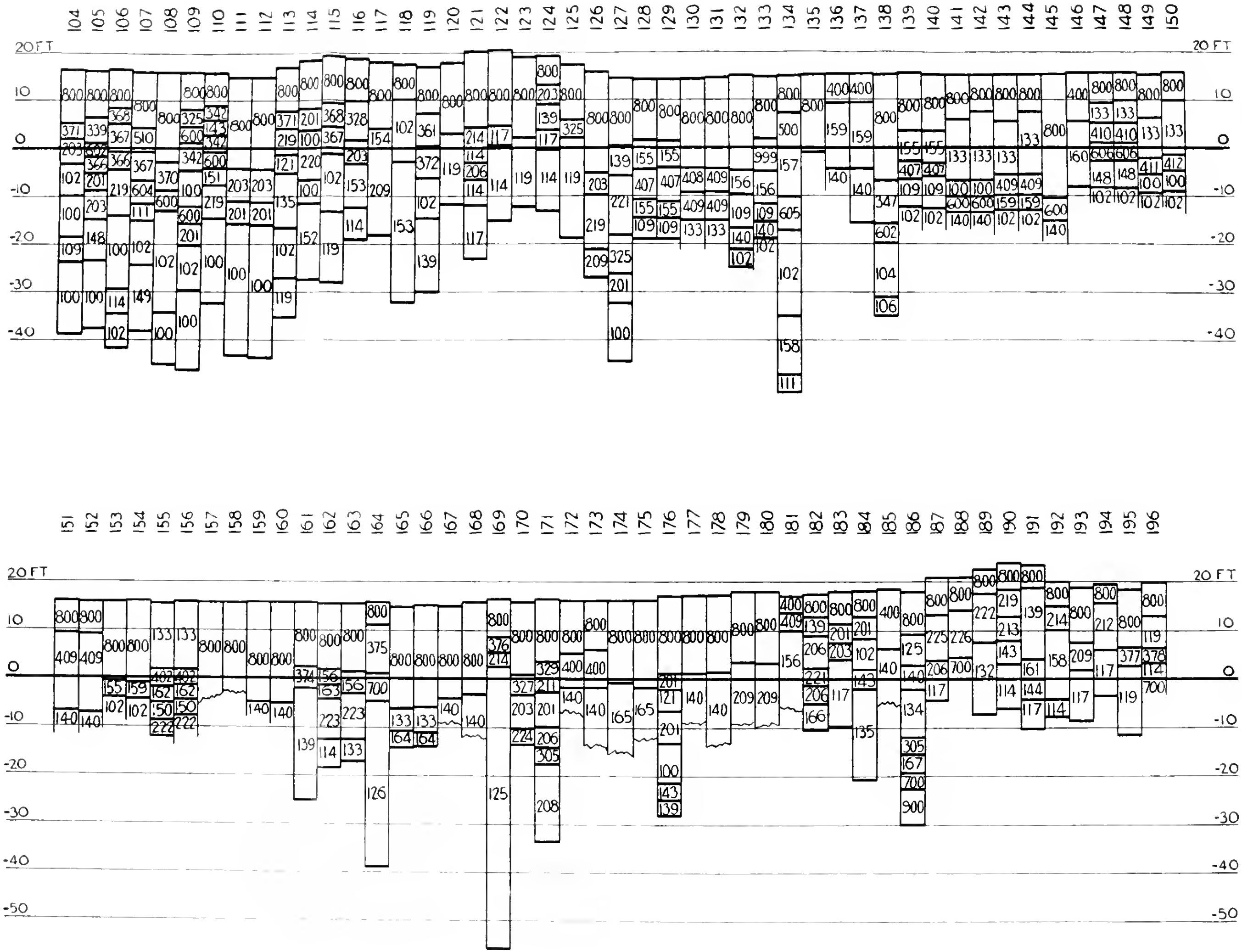
The following data have been furnished by A. H. French, engineer, Town of Brookline. — Taken from sewer profiles giving maximum depth of soft material within the length of black lines shown on map of Town.

		Surface Elevation.	Filling.	Elevation, Bottom of Mud.	Maximum Depth.
124.	Wilson Street	54	..	44	10
125.	Pond Avenue	20	..	—15	35
126.	Netherlands Road	17	11	—25	42
127.	Longwood Playground	18	12	—20	38
128.	Stearns Road	23	..	—5	28
129.	Brook Street	20	11	—35	55
130.	Bowker Street	21	..	7	14
131.	Kent Street	21	.	3	18
132.	Beacon Street	22	..	—16	38
133.	Beacon Street	20	..	—26	46
134.	Beacon Street	22	..	Piles; no data.	
135.	Beacon Street	21	..	—4	25
136.	Parkman Street	33	..	—5	38
137.	Parkman Street	30	20	12	18
138.	Kenwood Street	47	40	13	34
139.	Columbia Street	48	40	15	33
140.	Gibbs Street	44	39	8	36
141.	Beals Street	45	39	0	45
142.	Stedman Street	45	39	13	32
143.	Stedman Street	45	39	3	42
144.	Devotion Street	46	39	32	14
145.	Copley Street	55	..	28	27
146.	Crowninshield Road	51	38	..	..
147.	St. Paul Street	24	..	3	21
148.	Riverdale Road	20	12	—39 (lowest)	59
149.	Brookline Ave. Playground	16	11	—5	21

PLATE III
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS.
JANUARY, 1914.
WORCESTER ON
BOSTON FOUNDATIONS.

BOSTON PENINSULAR 104-196

See map for locations of borings and table of soil formations for meaning of numbers.



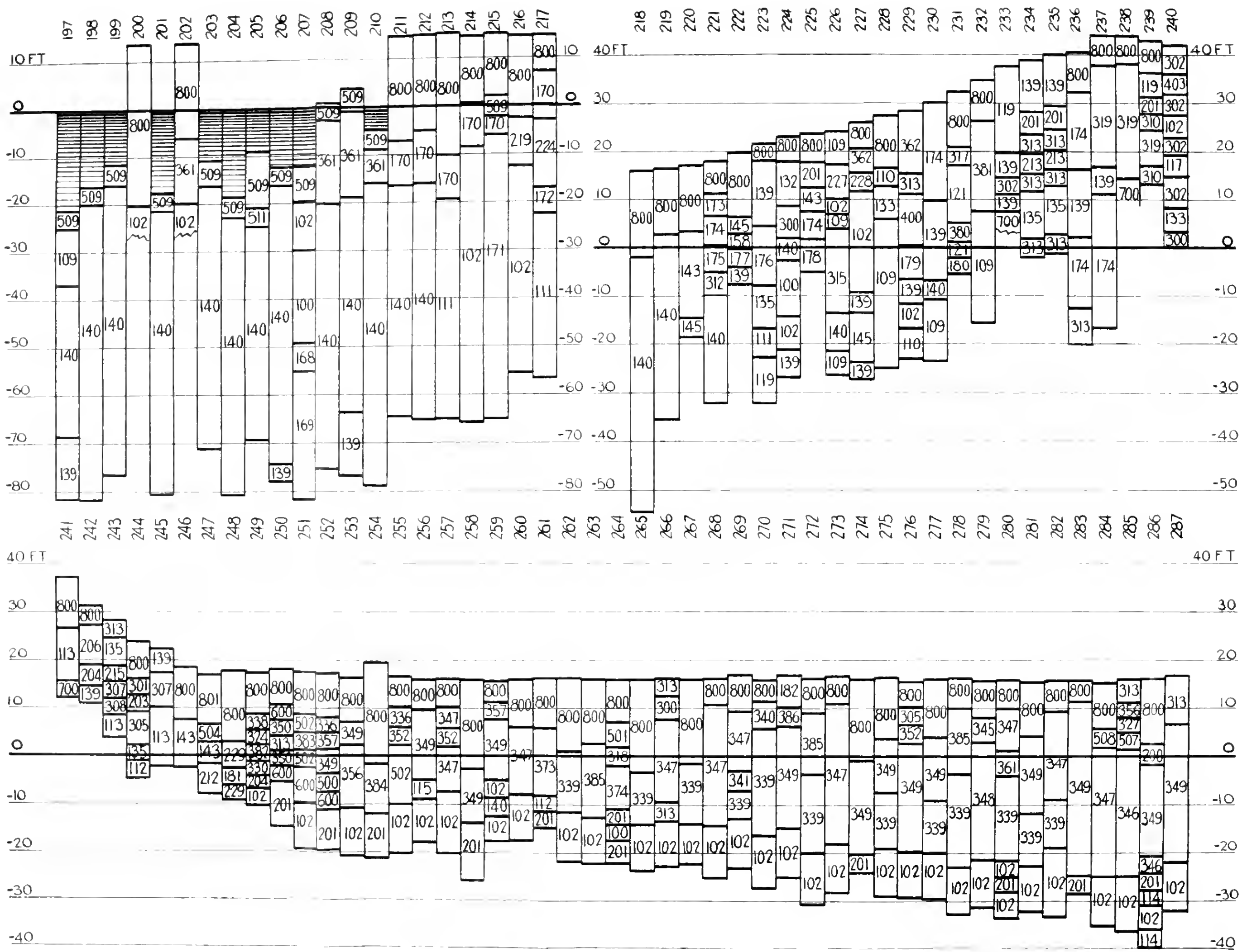


PLATE IV

JOURNAL BOSTON SOCIETY OF CIVIL ENGINEERS. JANUARY, 1914. WORCESTER ON BOSTON FOUNDATIONS.

BOSTON PENINSULAR 197-287

See map for locations of borings and table of soil formations for meaning of numbers.

PLATE V
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS.
JANUARY, 1914.
WORCESTER ON
BOSTON FOUNDATIONS.

BOSTON PENINSULAR 288-408

See map for locations of borings and table of soil formations for meaning of numbers.

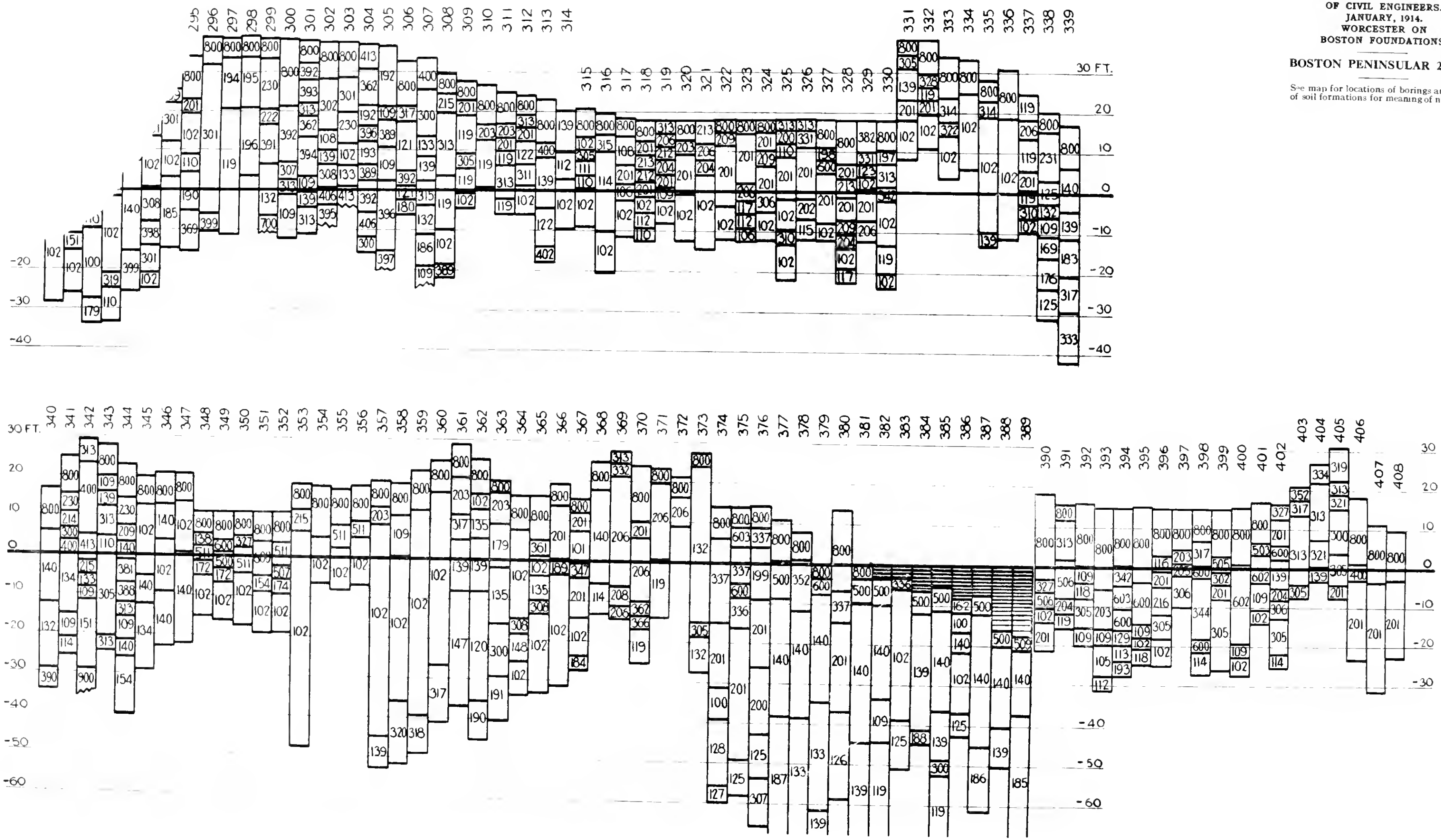


PLATE VI
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS.
JANUARY, 1914.
WORCESTER ON
BOSTON FOUNDATIONS.

BOSTON PENINSULAR 409-503

See map for locations of borings and table of soil formations for meaning of numbers.

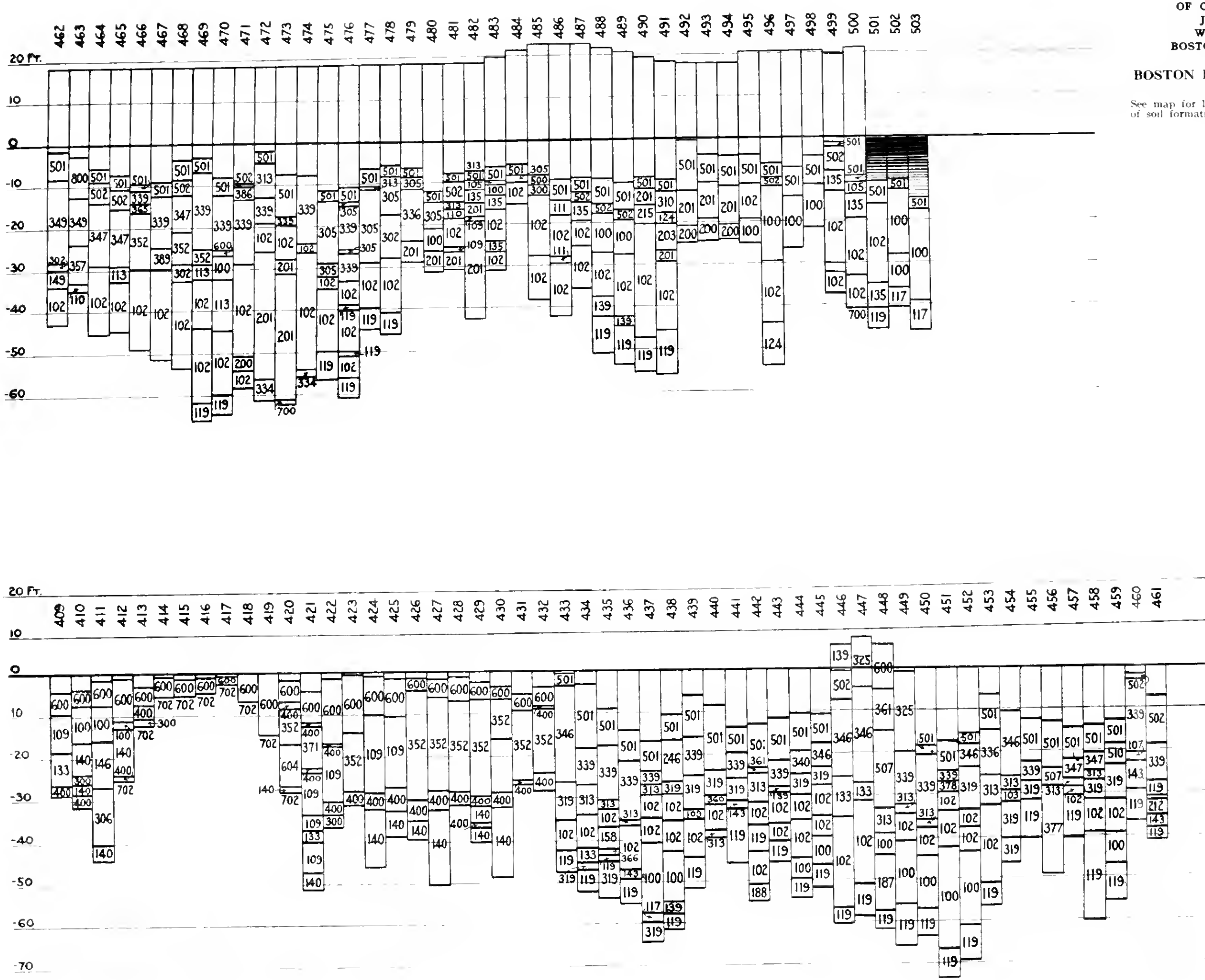


PLATE VII

JOURNAL BOSTON SOCIETY OF CIVIL ENGINEERS.
JANUARY, 1914.
WORCESTER ON BOSTON FOUNDATIONS.

BOSTON PENINSULAR 504-609

See map for locations of borings and table of soil formations for meaning of numbers.

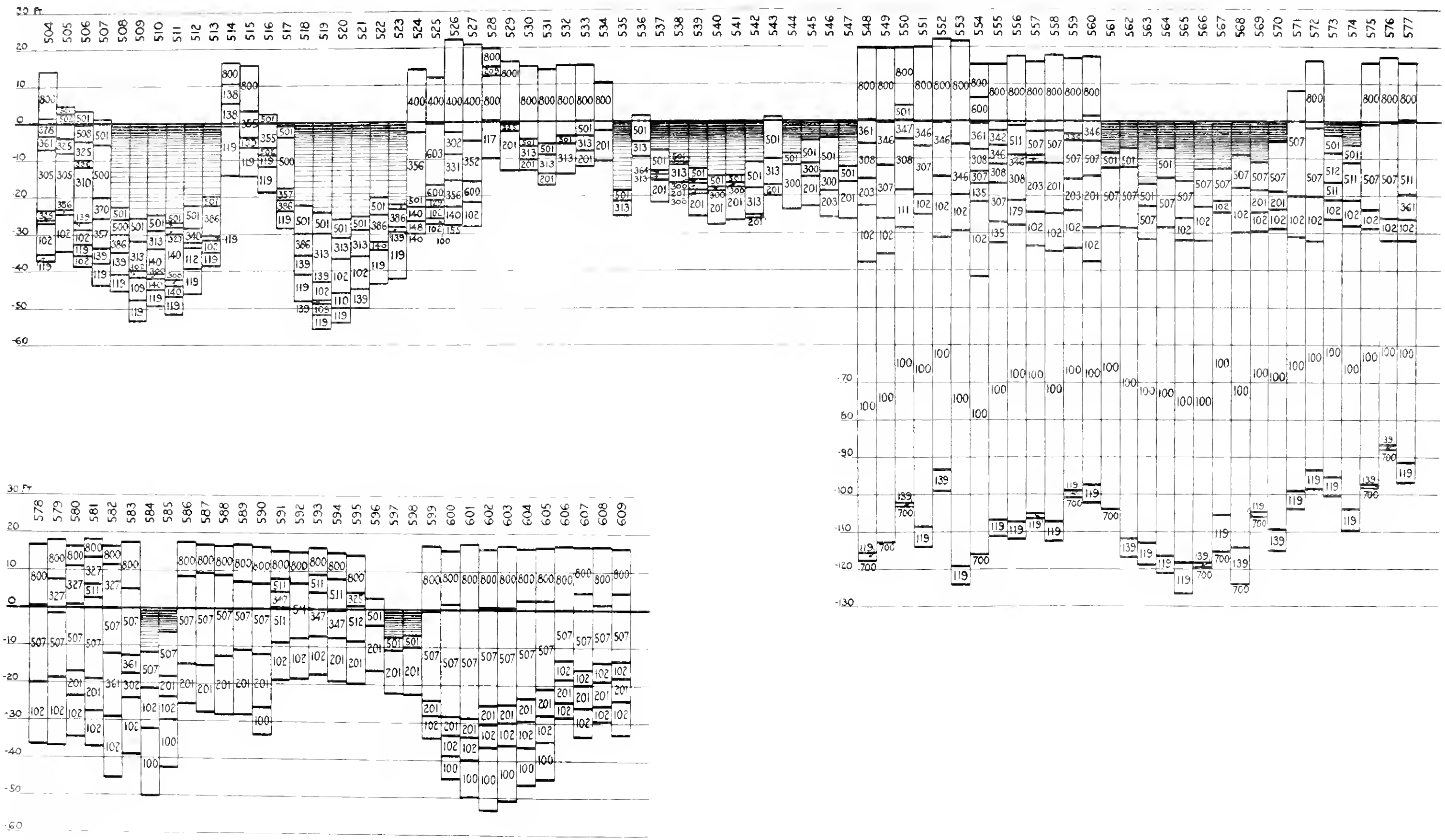


PLATE VIII
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS.
JANUARY, 1914.
WORCESTER ON
BOSTON FOUNDATIONS

BOSTON PENINSULAR 610–708

See map for locations of borings and table of soil formations for meaning of numbers

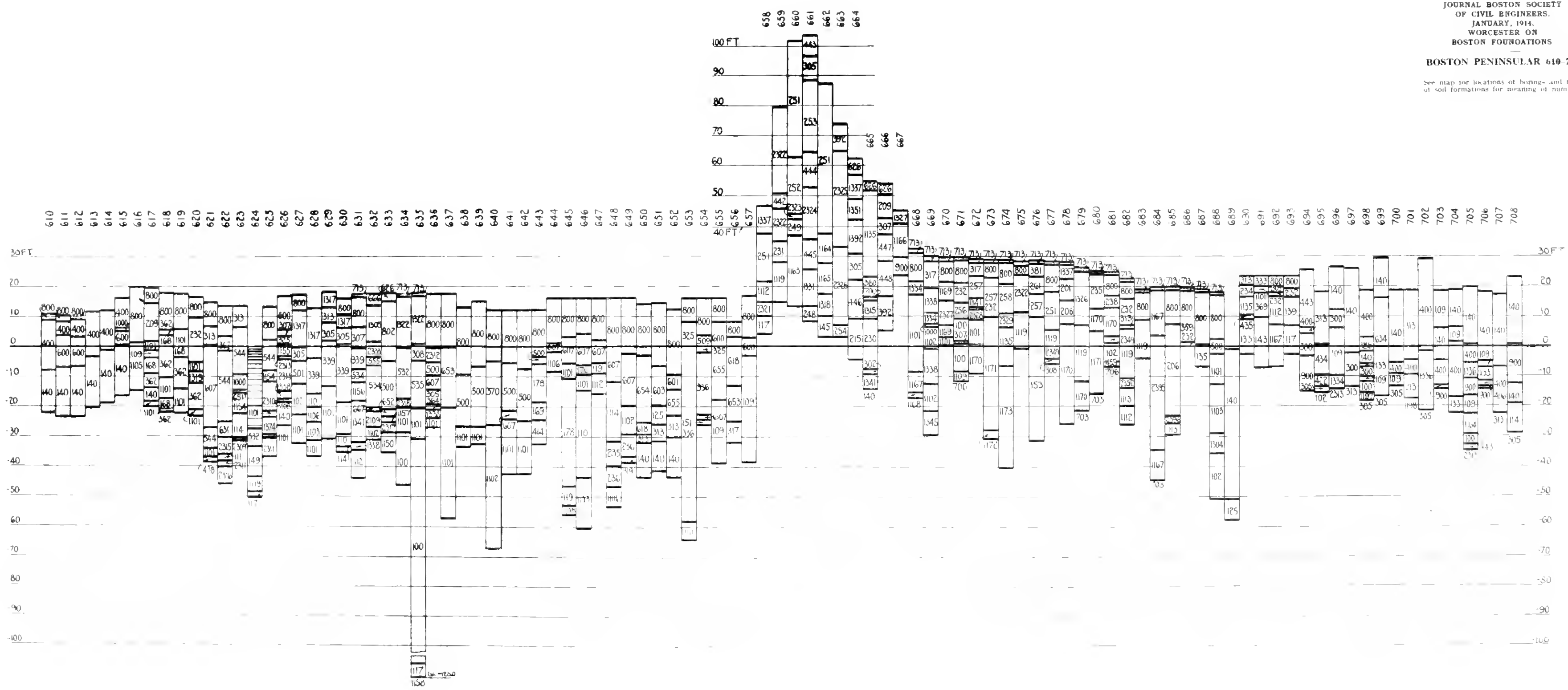


PLATE IX
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS.
JANUARY, 1914
WORCESTER ON
BOSTON FOUNDATIONS.

BOSTON PENINSULAR 709-802

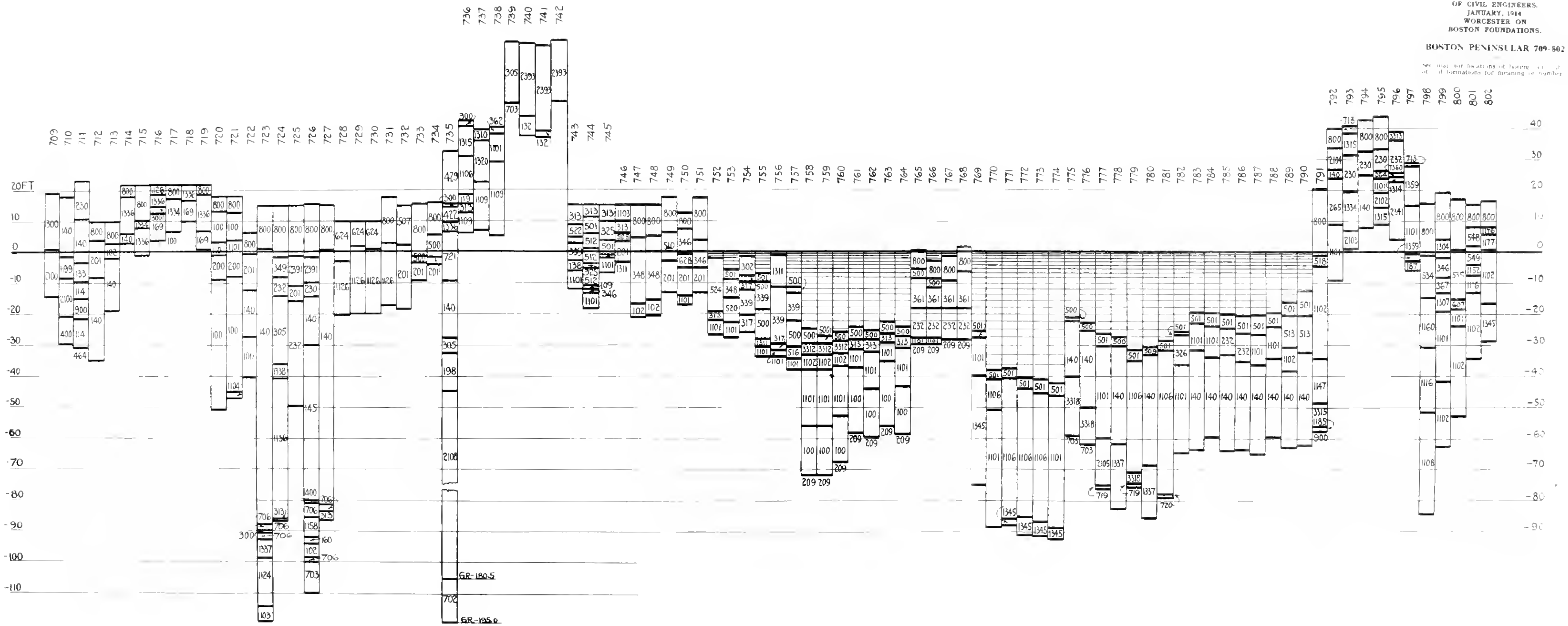


PLATE X
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS
JANUARY, 1914
WORCESTER ON
BOSTON FOUNDATIONS

SOUTH BOSTON

PLATE XI
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS
JANUARY, 1914
WORCESTER ON
BOSTON FOUNDATIONS

SOUTH BOSTON 1-213

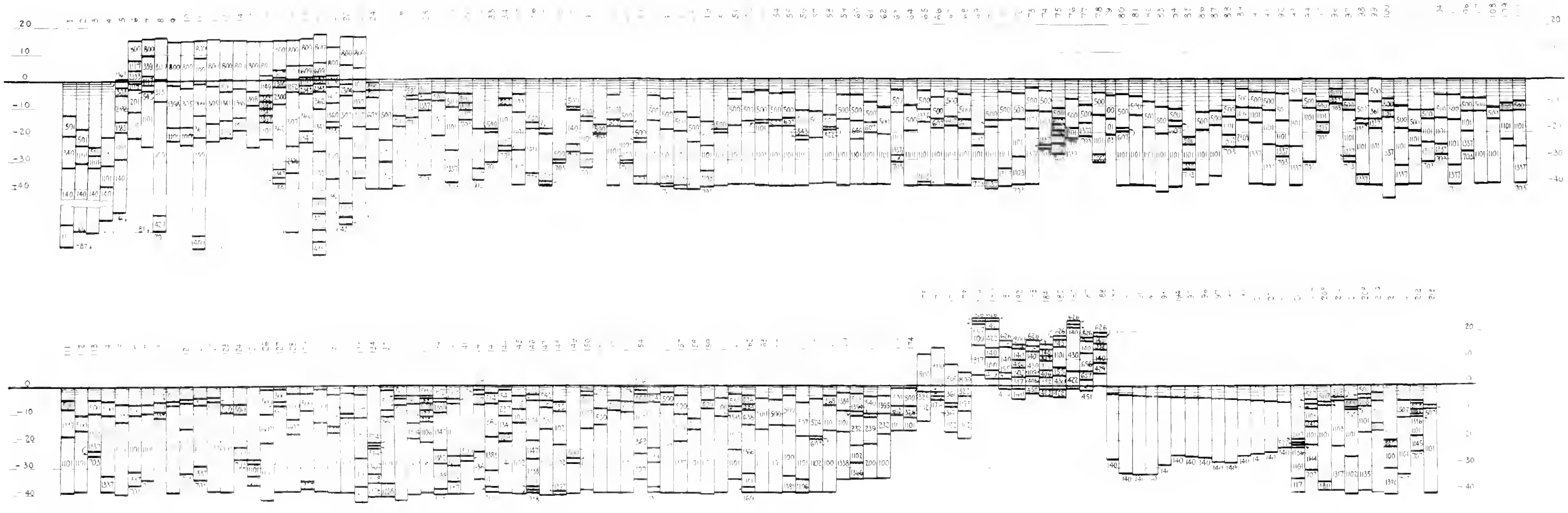


PLATE XII
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS.
JANUARY, 1914.
WORCESTER ON
BOSTON FOUNDATIONS.

SOUTH COVE DISTRICT

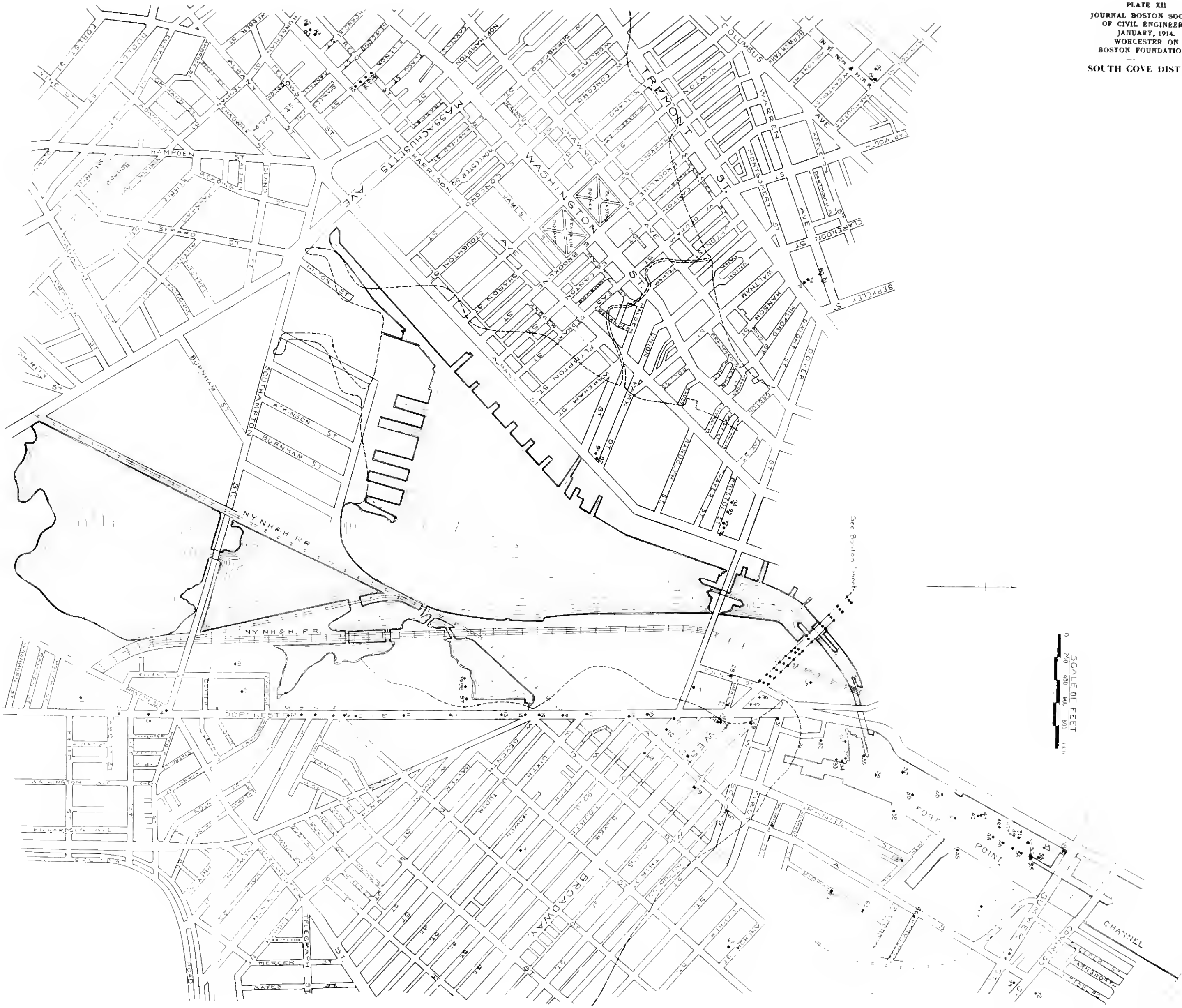


PLATE XIII
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS
JANUARY
WORCESTER ON
BOSTON FOUNDATIONS

SOUTH COVE DISTRICT

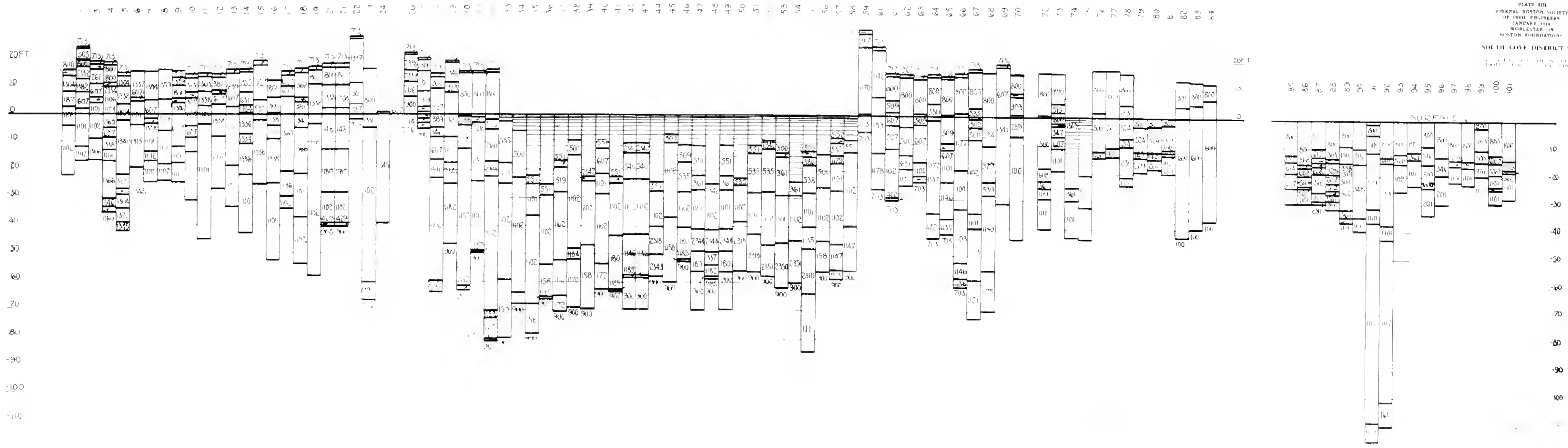
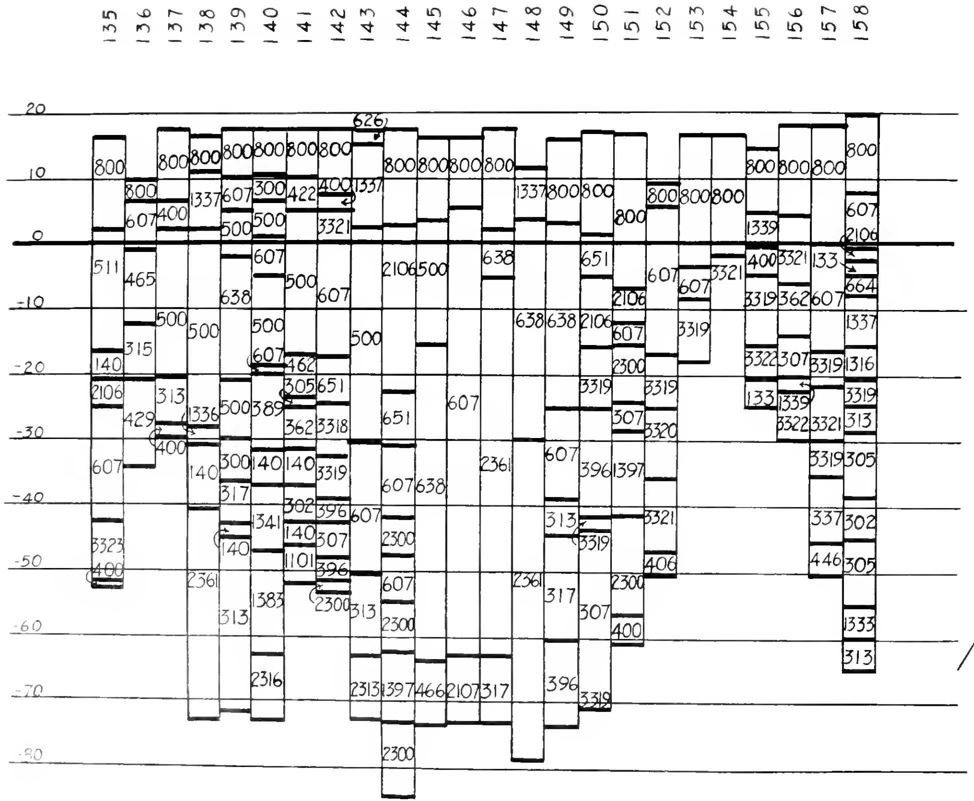


PLATE XIV
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS.
JANUARY, 1914.
WORCESTER ON
BOSTON FOUNDATIONS.

SOUTH COVE DISTRICT 135–158

See map for locations of borings and table of soil formations for meaning of numbers



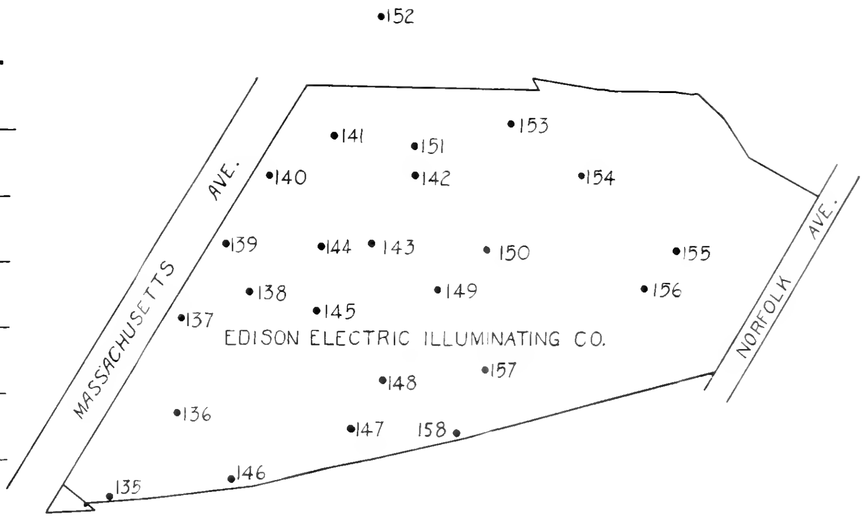


PLATE XV
JOURNAL BOSTON SOCIETY OF CIVIL ENGINEERS
JANUARY, 1914.
WORCESTER ON BOSTON FOUNDATIONS.

BACK BAY AND ROXBURY

PLATE XVI
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS
JANUARY, 1914
WORCESTER ON
BOSTON FOUNDATIONS

BACK BAY AND ROXBURY [illegible]

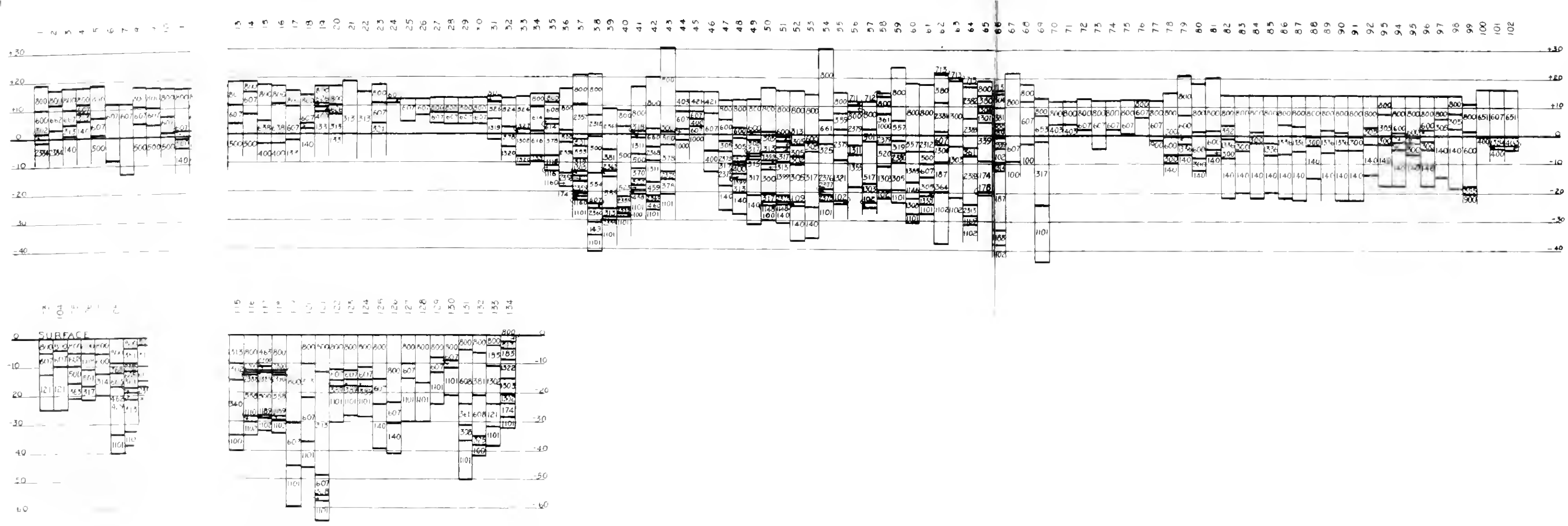


PLATE XVII
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS.
JANUARY, 1914.
WORCESTER ON
BOSTON FOUNDATIONS.

BROOKLINE

PLATE XVIII
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS
JANUARY, 1914
WORCESTER ON
BOSTON FOUNDATIONS

BROOKLINE 1-123

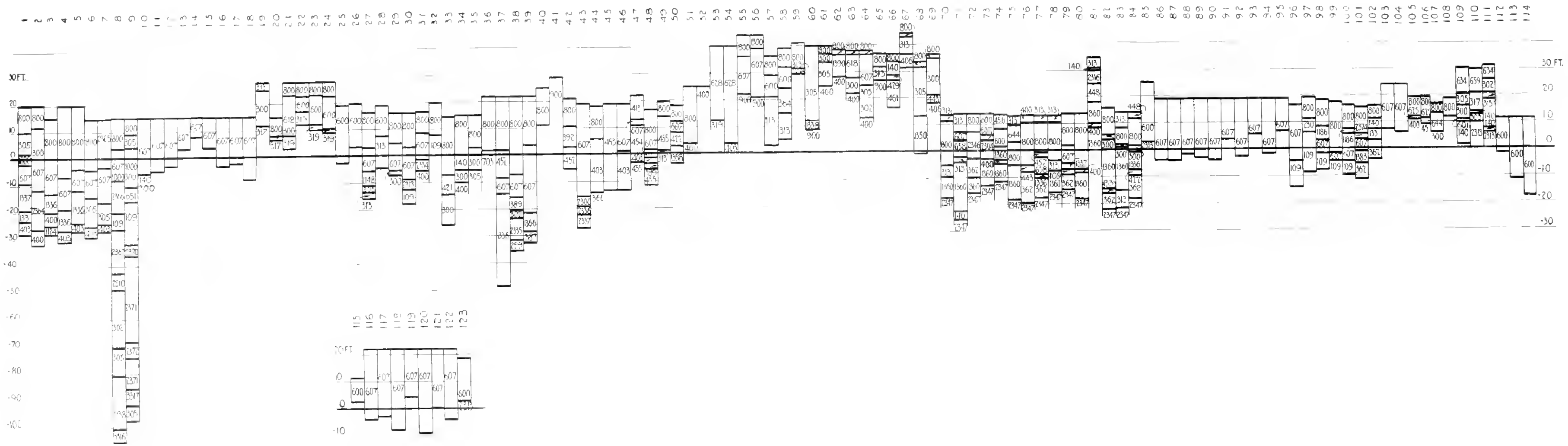


PLATE XIX
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS
JANUARY, 1914
WORCESTER ON
BOSTON FOUNDATIONS

HARVARD SQUARE DISTRICT

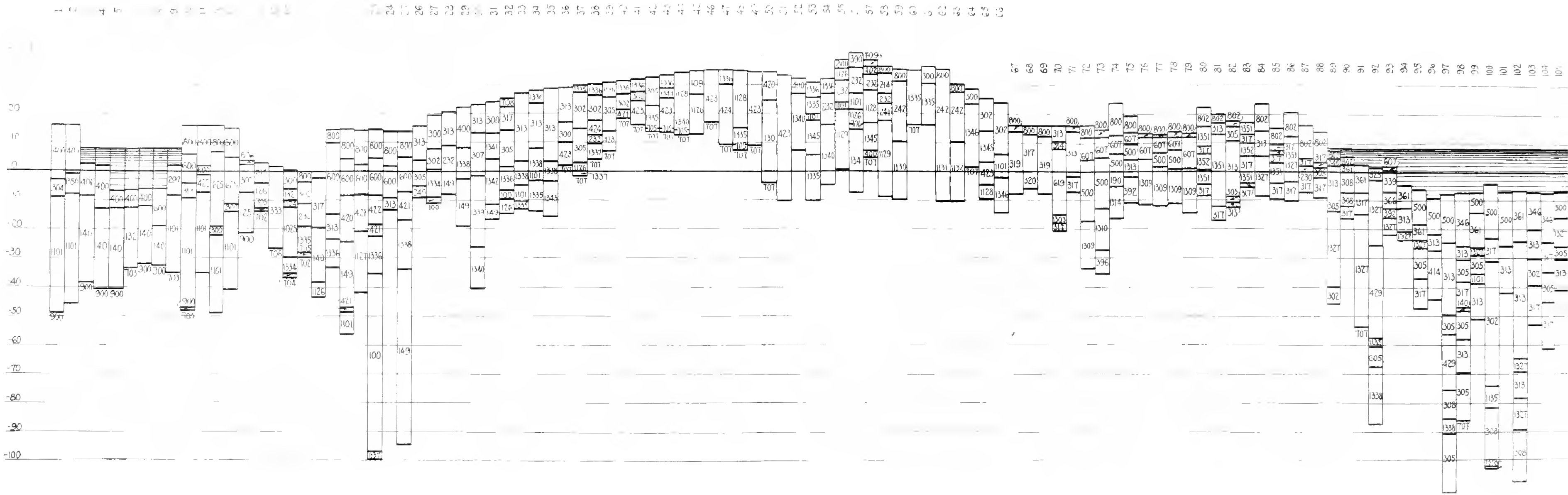

20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100

PLATE XX
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS
JANUARY, 1914
WORCESTER ON
BOSTON FOUNDATIONS.

HARVARD SQUARE 1–147

See map for locations of borings and table of soil formations for meaning of numbers.

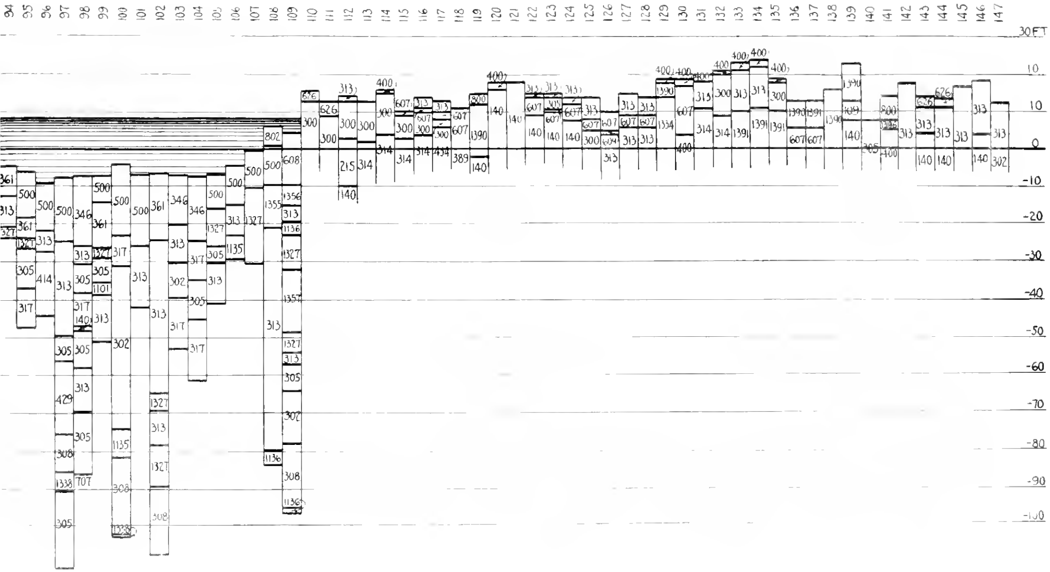


PLATE XXI
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS
JANUARY, 1914
WORCESTER ON
BOSTON FOUNDATIONS

EAST CAMBRIDGE

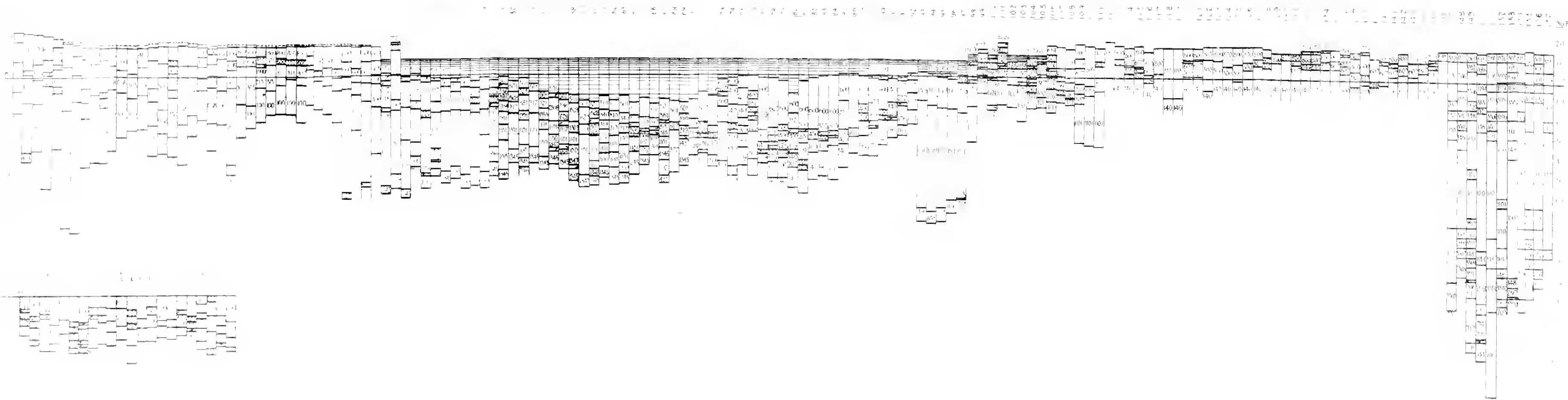


PLATE XIII

BOSTON SOCIETY OF CIVIL ENGINEERS

EAST CAMBRIDGE

PLATE XXIII
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS
JANUARY, 1914
WORCESTER ON
BOSTON FOUNDATIONS

CHARLESTOWN

PLATE XXIV
JOURNAL BOSTON SOCIETY OF CIVIL ENGINEERS.
JANUARY, 1914.
WORCESTER ON BOSTON FOUNDATIONS.

CHARLESTOWN 1-85

See map for locations of borings and table of soil formations for meaning of numbers.

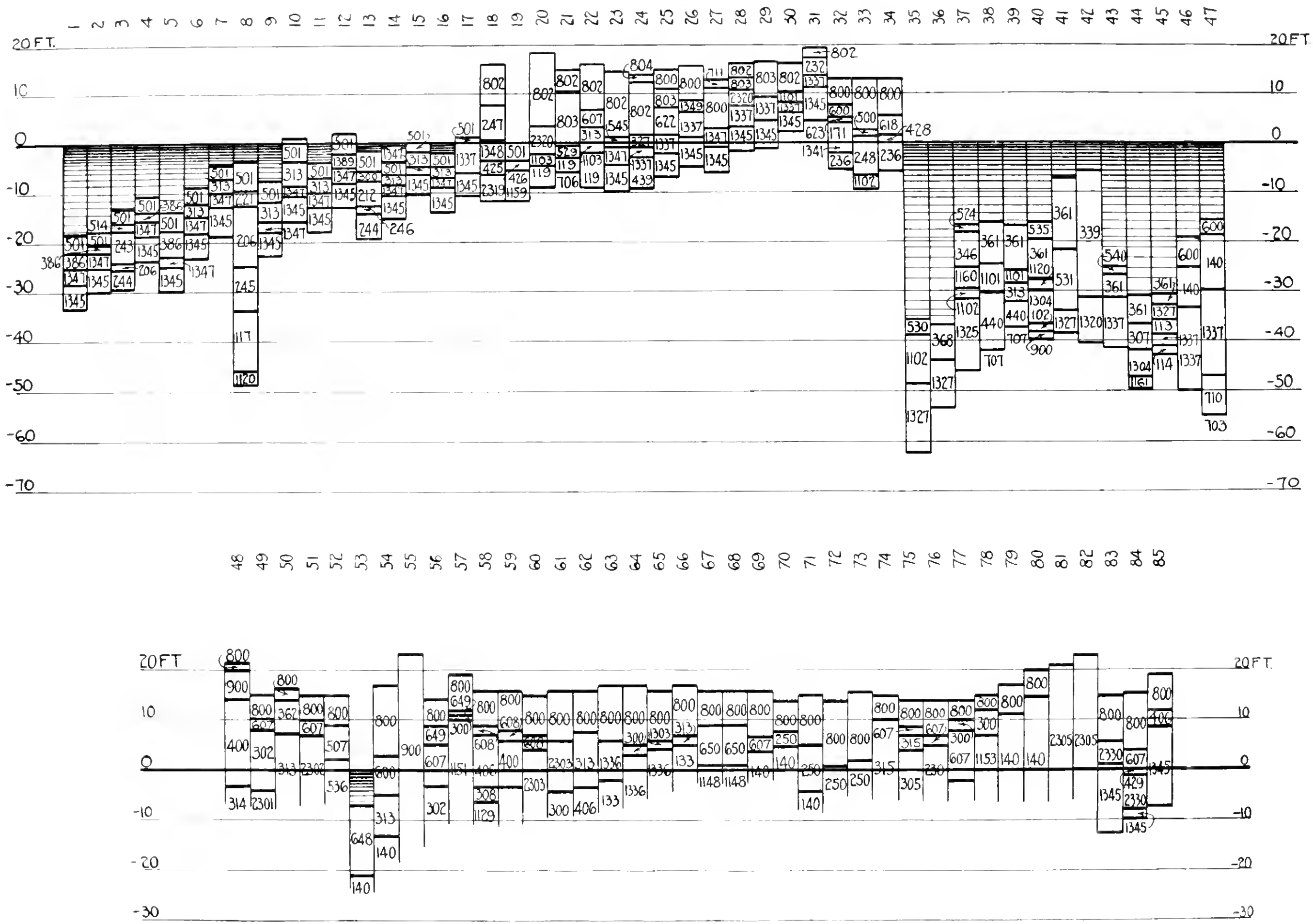
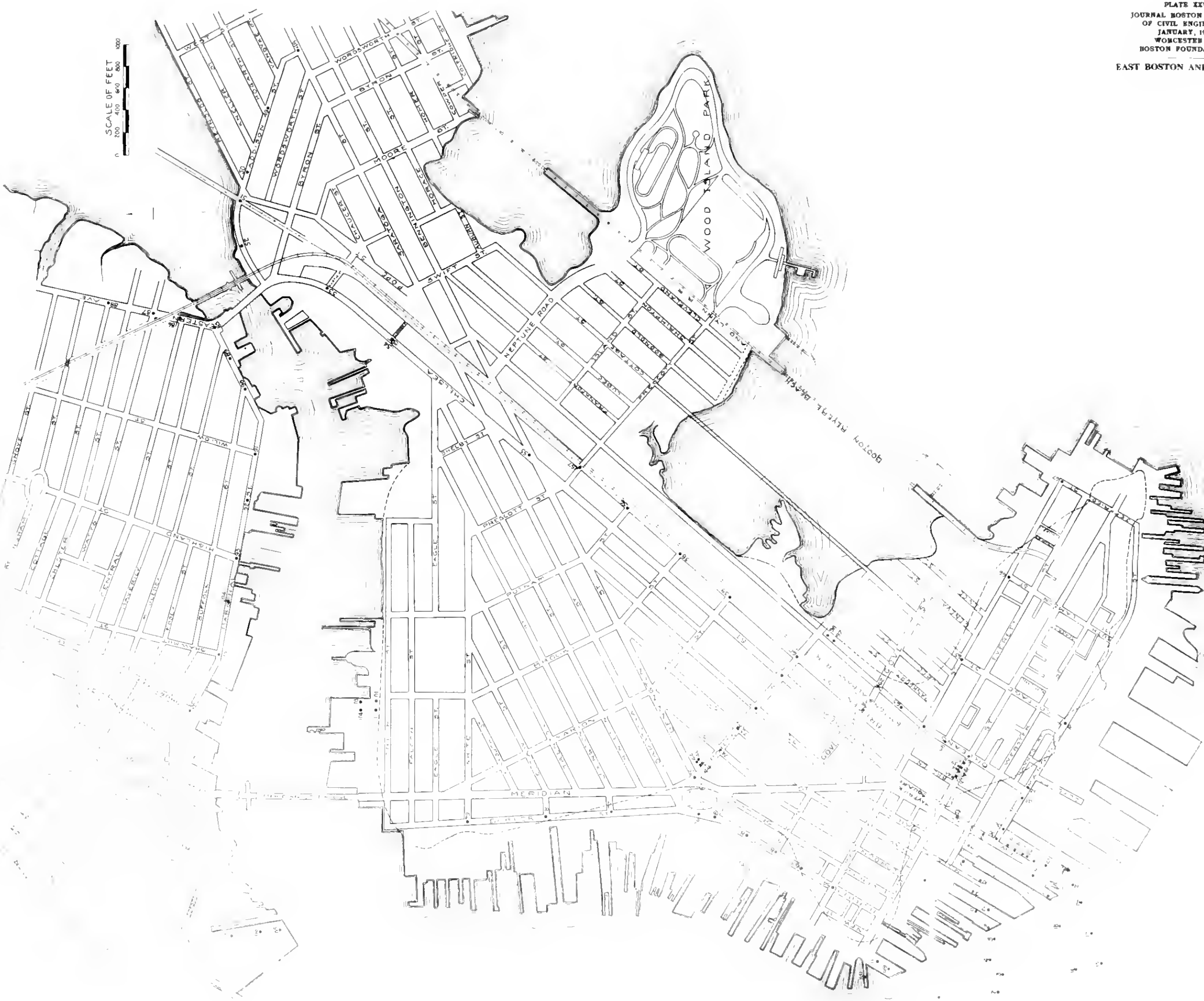


PLATE XXV
JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS.
JANUARY, 1914.
WORCESTER ON
BOSTON FOUNDATIONS

EAST BOSTON AND CHELSEA



DARTMOUTH
CLARENDON
BEACON ST
COMMONWEALTH AVE
BOYLSTON
ARLINGTON
PUBLIC GARDEN
CHARLES ST
CHARLES
LOUISBURG SQUARE
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ANDERSON ST
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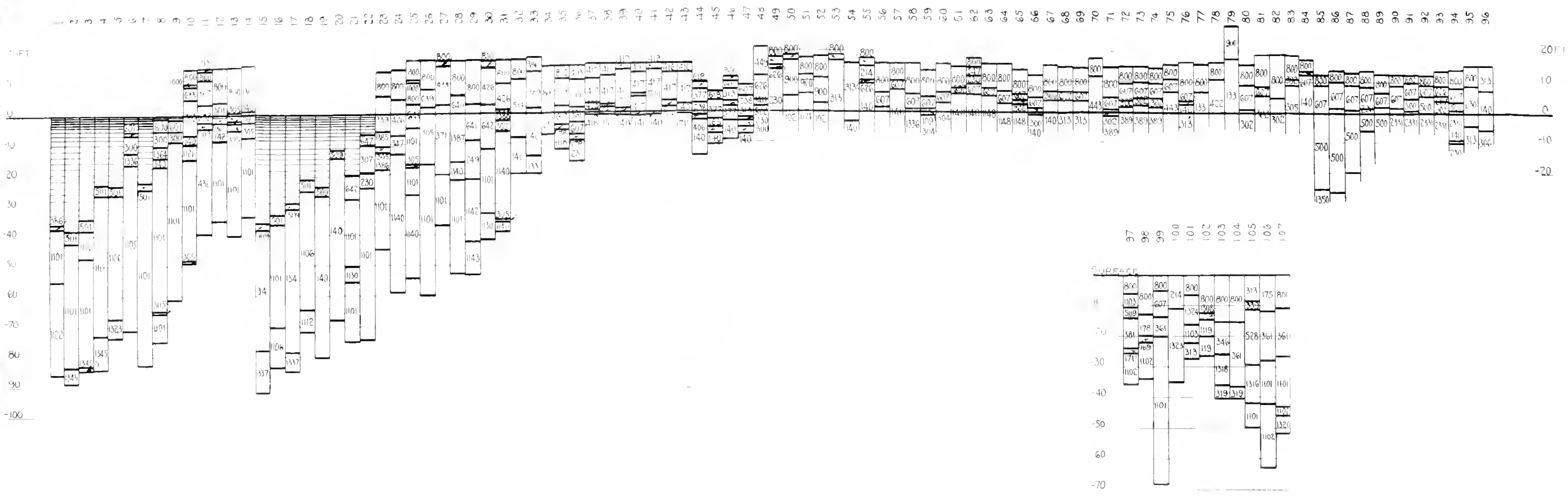

PLATE XXVI
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PAPERS AND DISCUSSIONS

THE MAIN DRAINAGE WORKS PROPOSED FOR NEW YORK.

By George A. Soper, Member Boston Society of Civil Engineers.

(Presented before the Sanitary Section, December 3, 1913.)

At the present time, New York discharges its sewage into the rivers and other arms of the harbor without purification or sanitary regulation of any kind. There are no restrictions as to the quantity or circumstances under which the sewage is discharged and, as objectionable consequences have followed this practice, it is proposed that a system of main drainage and sewage disposal works shall be constructed.

The main drainage system has been proposed by the Metropolitan Sewerage Commission, a board of consulting engineers created by the city and state to make a thorough study both as to the need and nature of protective measures. It has existed for nearly seven years, but has been provided with funds and an organization suitable for effective work only for about four years.

The fundamental investigations have been completed and recommendations, including preliminary plans and estimates of cost, are nearly finished. The final report will be presented to the mayor before May, 1914. The next step should be construction and a special commission intrusted with the work.

Note. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, by April 15, 1914, for publication in a subsequent number of the Journal.

The present Board is not seeking authority to carry its recommendations into effect.

Scope of the Commission's Work.

The legislature which required the city of New York to appoint the Metropolitan Sewerage Commission, defined, by Chapter 639 of the Laws of 1906, the work which the Commission should perform. Briefly, its duty was to continue and extend the work of the New York Bay Pollution Commission (created in 1903)* and answer the following questions:

1. Is it desirable and feasible for New York and the municipalities in its vicinity to agree upon a general plan or policy of sewage disposal which will protect the waters of the harbor against unnecessary and injurious pollution?

2. What methods of collecting and disposing of the sewage and other wastes which pollute, or may eventually pollute, these waters are most worthy of consideration?

3. Is it desirable to establish a sewerage district in order properly to dispose of the wastes, and, if so, what should be its limits and boundaries?

4. What is the best system of administrative control for the inception, execution and operation of a plan for main drainage?

In order to answer the foregoing questions, the Commission made a study of the circumstances and conditions under which the sewage was being collected and disposed of; the sanitary jurisdiction which could be exercised over the waters by the cities, states and general government, all of which have certain definite powers with regard to the harbor; the necessity for regulating the disposal of the sewage and the amount and character of the improvement which was required.

Up to April, 1910, the Commission's field of investigation was as much in New Jersey as in New York. For the purpose of study, it had mapped out in 1908 a territory of about equal extent in each state and called it the Metropolitan Sewerage District. From 1910 to 1914, during which the plans for main

* Pollution of the Tidal Waters of New York City and Vicinity, by George A. Soper, *Journal of the Association Engineering Societies*, Vol. XXXVI, No. 6, June, 1906, pp. 272–303.

drainage were in preparation, only that part of the district which lies in New York State was considered. This restriction was made necessary by the great extent of the territory and the need of providing definite plans for New York at the earliest possible moment. The same principles of collection and disposal are believed to apply to each side of the state line; consequently the plans which the Commission is making for New York afford a general illustration of the schemes of main drainage which would probably be found suitable for that part of the Metropolitan District which lies in New Jersey.

The state line divides the harbor about in the middle, and it is claimed that this fact carries to each state an equal share in the harbor's sewage absorptive capacity. The contention is more of a legal than an engineering one, but the respective rights of the two states should not be overlooked in making plans for the disposal of New York's sewage. If the two states are to share equally, New Jersey has a large asset which it can draw upon for the disposal of its sewage in the future, while New York must restrict its use of the water for sewage disposal considerably beyond what would otherwise be necessary and sufficient. The Metropolitan Sewerage Commission's plans have been made sufficiently elastic to provide for either contingency, but the projects which will be recommended for early construction assume that New York will be allowed to make use of more than one-half of the harbor's capacity.

The Commission has performed a large amount of technical work. Extensive tidal studies were carried on in coöperation with the United States Coast and Geodetic Survey to determine the force and direction of the currents, principally to determine the extent to which the ebb and flow of the water caused the sewage to be carried out to sea, experiments were made upon the dispersion of sewage in the water, and studies were conducted to determine the rate at which sewage solids were disposed of by liquefaction and oxidation. The relation of dissolved oxygen to the disposal of the sewage was studied with a thoroughness believed to be unprecedented in such investigations, the total number of analyses being about eight thousand. Incubation tests were made to determine the rate at which sewage absorbed

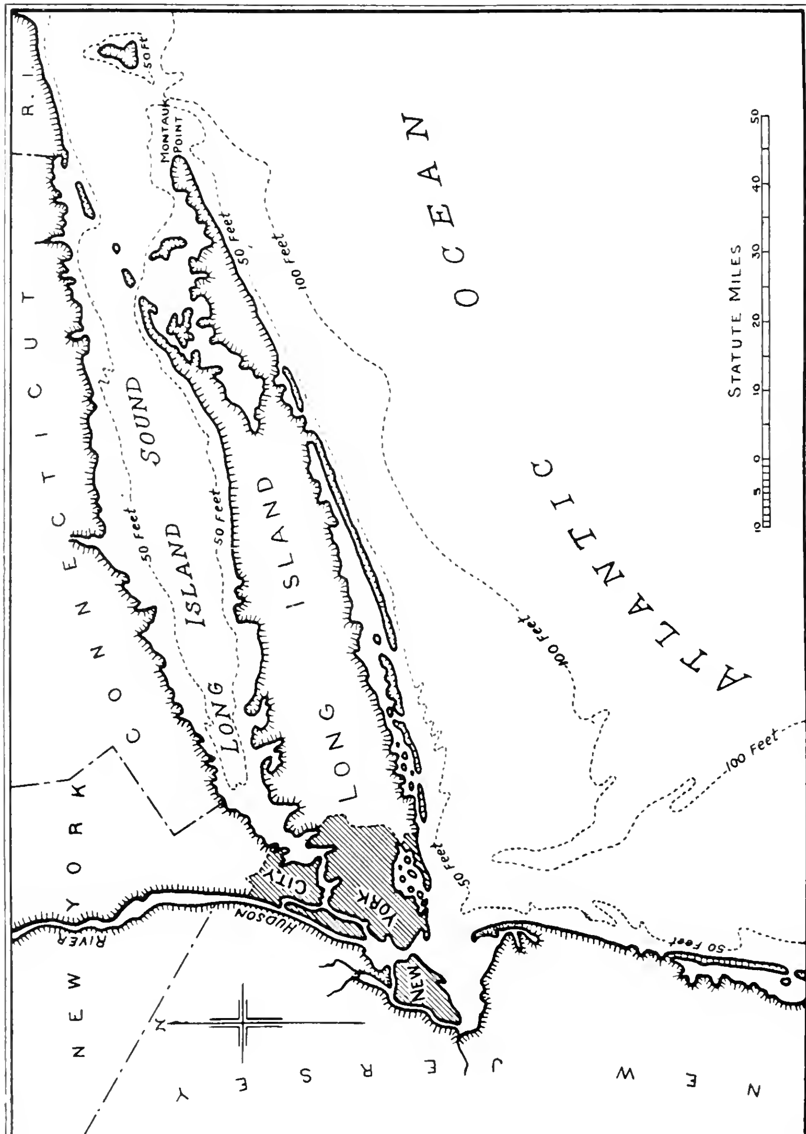

FIG. 1. SITUATION OF NEW YORK CITY WITH REFERENCE TO THE COASTLINE, SHOWING THE UNFAVORABLE SITUATION OF THE INNER HARBOR FOR SEWAGE DISPOSAL.

dissolved oxygen from water under various circumstances, and investigations were made into the rate at which oxygen was absorbed from the air. A large number of projects were worked up to cover intercepting and collecting sewers, disposal plants, submerged outlets and other engineering features.

Space does not permit mention of all the lines of study which were pursued, but the foregoing show that the scope of the Commission's work was broad and that no pains were spared to make the investigations adequate.

Main Elements of the Problem.

At the outset of the investigation there was little information available on any of the subjects which the Commission was required to study. In determining what was required in the way of public works for the protection of the harbor, it was impossible to be guided as much by general principles or by the practices of other cities as is often practicable in work of this character. The situation is unique and complicated. The harbor is large, of intricate form and possessed of two widely separated ocean entrances, the tidal range being about $4\frac{1}{2}$ ft. at one entrance and $7\frac{1}{2}$ ft. at the other. The resultant ebb flow is about 2 702 million cu. ft. per twelve lunar hours at the main outlet and practically zero at the other.

The territory is of great extent, about 700 sq. miles, and includes about eighty municipalities. The population presents every stage of concentration, from the congestion of a great city to the sparse settlement of the open country. The number of inhabitants, about 6 000 000 in 1910, will be about 11 600 000 by 1940, and the quantity of sewage, about 765 000 000 gal. in 1910, will be about 1 719 000 000 gal. by 1940.

The sewage, collected for the most part in short sewers built on the combined plan, is discharged mostly at, or close to, the shores near the level of low tide, usually creating offensive conditions at the outlets.

TABLE 1. — ESTIMATED VOLUMES OF STORM WATER AND DOMESTIC SEWAGE ENTERING VARIOUS PARTS OF THE HARBOR FROM NEW YORK CITY.

Drainage to	Acres of Land.			Millions of Cubic Feet Daily.				Per Cent. of Volume of Sewage.		Population. Thousands.	Persons per Acre.
	Net.	Parks.	Total.	Rain.	C.	Run-off.	Sewage.	Rain.	Run-off.		
Hudson[1]	5 122	349	5 471	2.39	85	2.03	33.50	7.1	6.1	1 562.6	306
Harlem[2]	8 783	1 759	10 542	4.61	60	2.77	40.29	10.7	6.9	2 105.8	239
Upper East River[3]	39 717	2 431	42 148	18.43	40	7.37	6.64	277.6	111.0	304.8	8
Lower East River	16 852	2 229	19 081	8.33	80	6.66	64.6	12.9	10.3	3 785.9	198
Jamaica Bay[4]	53 659	....	....	23.47	50	11.74	27.20	86.3	43.2	1 415.7	26
Kill van Kull[5]	6 647	....	....	2.91	60	1.75	7.91	36.8	22.1	432.9	65
Upper Bay[5]	12 519	458	12 977	5.69	70	3.98	25.80	22.1	15.4	1 617.9	129

[1] From Harlem River to the Battery.
[2] Includes sewage from Hudson area, 573 acres, Harlem River to northern line of city.
[3] Agrees with Preliminary Report IV of the Metropolitan Sewerage Commission.
[4] Agrees with Preliminary Report III.
[5] Agrees with Preliminary Report V.

Population and sewage:
- Manhattan and Brooklyn as of 1960
- Queens 1950
- Bronx 1940

C, Assumed percentage of rain flowing to streams.

TABLE 2. — VOLUMES OF WATER AT LOW TIDE, IN TIDAL PRISM, NET DISCHARGE FROM THE SEVERAL DIVISIONS OF THE HARBOR AND RATIOS OF VOLUME OF SEWAGE DIRECTLY TRIBUTARY TO VOLUME OF WATER IN THE TIDAL PRISM.

QUANTITIES GIVEN IN MILLIONS OF CUBIC FEET.

Division of the Harbor.	Volume of Water below Mean Low Tide.	Net Ebb Flow in Twelve Lunar Hours.	Water in the Prism.	Sewage Tributary to the Division. Year 1910.		Year 1940.	
				Volume.	Ratio.	Volume.	Ratio.
Harlem River	285	15	148	6.9	1:21	17.5	1:8
Hudson River	12 330	1 087	1 697	9.2	1:185	20.9	1:81
Upper East River	5 512	..	1 869	1.5	1:1246	6.9	1:271
Lower East River	4 174	100	552	17.1	1:323	31.5	1:17
Upper Bay	12 970	1 283	2 541	4.4	1:578	8.2	1:310
Newark Bay	1 542	105	1 071	0.9	1:119	2.1	1:510
Kill van Kull	728	88	150	0.5	1:300	1.6	1:94
Jamaica Bay	2 029	....	1 977	3.7	1:534	11.3	1:175
	39 570	...	10 005	44.2	1:234	100.0	1:103

TABLE 3. — RATIOS OF VOLUME OF SEWAGE DIRECTLY TRIBUTARY PER TWELVE LUNAR HOURS TO: — (*a*) NET EBB FLOW. (*b*) VOLUME OF WATER IN THE HARBOR AT MEAN LOW TIDE. QUANTITIES ARE IN MILLIONS OF CUBIC FEET.

Division of the Harbor.	Net Ebb Flow.	Below Low Tide	Sewage Tributary to the Division. Year 1910.			Year 1940.		
			Volume.	Ratio. (*a*).	Ratio. (*b*).	Volume.	Ratio. (*a*).	Ratio. (*b*).
Harlem River	15	285	6.9	1:2	1:41	17.5	1:0.86	1:16
Hudson River	1 087	12 330	9.2	1:118	1:1340	20.9	1:52	1:590
Upper East River	....	5 512	1.5	....	1:3675	6.9	....	1:790
Lower East River	100	4 174	17.1	1:6	1:244	31.5	1:3	1:132
Upper Bay	1 283	12 970	4.4	1:292	1:2950	8.2	1:156	1:1580
Newark Bay	105	1 542	0.9	1:117	1:1713	2.1	1:50	1:725
Kill van Kull	88	728	0.5	1:176	1:1470	1.6	1:55	1:455
Jamaica Bay	24	2 029	3.7	1:6	1:550	11.3	1:2	1:180
	2 702	39 570	44.2	1:61	1:896	100.0	1:27	1:396

TABLE 4. — SOLID, ORGANIC AND VOLATILE MATTERS IN SEWAGE DIRECTLY TRIBUTARY TO THE SEVERAL DIVISIONS OF THE HARBOR. QUANTITIES IN TONS PER TWELVE LUNAR HOURS.

Division of the Harbor.	Year.	Suspended Solid Matters.	Organic and Volatile Matters.					
			Total.	Dissolved.	Suspended.	Nitrogenous.	Fat, etc.	Carbon.
Harlem River	1910	52	70	35	35	26	9	35
	1940	111	148	74	74	56	18	74
Hudson River	1910	65	87	43	44	33	11	43
	1940	126	168	84	84	63	21	84
Upper East River	1910	12	16	8	8	6	2	8
	1940	43	57	29	28	21	7	29
Lower East River	1910	133	178	89	89	67	22	89
	1940	209	279	139	140	105	35	139
Upper Bay	1910	34	45	23	22	17	6	23
	1940	59	79	40	39	30	10	40
Newark Bay	1910	7	9	4	5	3	1	4
	1940	13	18	9	9	7	2	9
Kill van Kull	1910	3	4	2	2	2	0.6	2
	1940	9	12	6	6	4	2	6
Jamaica Bay	1910	23	30	15	15	11	4	15
	1940	59	79	39	40	30	10	39
Total	1910	329	439	219	220	165	55.6	219
	1940	629	840	420	420	318	105	420

TABLE 5. — SUSPENDED AND ORGANIC MATTERS WHICH WOULD BE CONTAINED IN THE SEWAGE DIRECTLY TRIBUTARY TO DIVISIONS OF THE HARBOR AFTER TREATMENT. QUANTITIES IN TONS PER TWELVE LUNAR HOURS.

Division of the Harbor.	Year.	Crude Sewage.		Sewage after Treatment.							
				Screens.		Sedimentation.		Chemical Precipitation.		Sprinkling Filters.	
		Sus.	Org.	Sus.	Org.	Sus.	Org.	Sus	Org.	Sus.	Org.
Harlem River	1910	52	70	44	63	21	49	7.8	35	5.2	21
	1940	111	148	94	153	44	104	16.6	74	11.1	44
Hudson River	1910	65	87	55	78	26	61	9.8	44	6.5	26
	1940	126	168	107	151	50	118	18.9	84	12.6	50
Upper East River	1910	12	16	10	14	5	11	1.8	8	1.2	5
	1940	43	57	37	51	17	40	6.4	28	4.3	17
Lower East River	1910	133	178	113	160	53	125	20.0	89	13.3	53
	1940	209	279	178	251	84	195	31.4	140	20.9	84
Upper Bay	1910	34	45	29	40	14	32	5.1	22	3.4	13
	1940	59	79	50	71	24	55	8.8	39	5.9	24
Newark Bay	1910	7	9	6	8	3	6	1.0	4	0.7	3
	1940	13	18	11	16	5	13	2.0	9	1.3	5
Kill van Kull	1910	3	4	3	4	1	3	0.5	2	0.3	1
	1940	9	12	8	11	4	8	1.4	6	0.9	4
Jamaica Bay	1910	23	30	20	27	9	21	3.4	15	2.3	9
	1940	59	79	50	71	24	55	8.8	40	5.9	24
Total	1910	329	439	280	394	132	308	49.4	219	32.9	131
	1940	629	840	535	755	252	588	94.3	420	62.9	252

It was difficult to form a definite opinion as to the dilution which the sewage received after its discharge into the harbor, for many confusing factors entered into the question. The conditions varied in different places according to the quantity of sewage discharged, the quantity of water available to receive it, the freshness of the water (by which is meant its oxygen content), the presence or absence of putrefying deposits, the temperature of the water and other factors. The objectionable conditions which it was necessary to note were neither trifling nor confined to the immediate vicinity of the sewer outfalls. Sections of the harbor, hundreds of acres in extent, were affected, some parts being worse than others, but all were more or less related to one another.

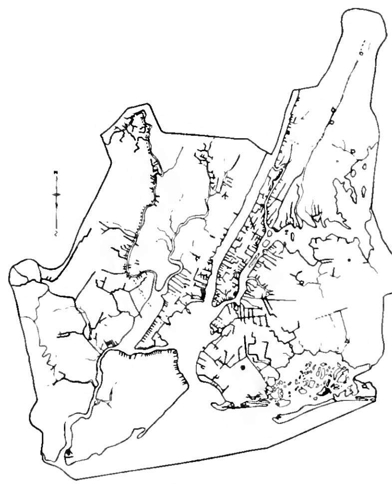

FIG. 2. THE METROPOLITAN SEWERAGE DISTRICT, SHOWING THE MAIN SEWERS AND POINTS OF DISCHARGE.

No greater mistake could be made than to liken the dilution to that which can be produced in a quiet tank or in a river flowing always in one direction, for the harbor currents oscillate, carrying the sewage back and forth indefinitely near its points of origin. At some points there is relatively little resultant discharge of water toward the sea, and while the oscillations produce a refreshing effect like that of breathing, the effect is limited. A float which was followed for 108 miles on its backward and forward course in the lower East River was finally taken up within about a mile of where it was set adrift. Unfortunately, the effects of the tide are least where they are most wanted. The innermost parts of the harbor are beyond the direct reach of the fresh, clean sea water.

The question of how much sewage could be disposed of by

Fig. 3. Path of a Float set Adrift in the Hudson River, showing the Slowness of the Seaward Movement of Polluted Water even in that Part of the Harbor where the Trend toward the Ocean is most Rapid.

direct discharge into the harbor was recognized at the outset to be of the utmost importance because of the expense which would have to be incurred if the sewage was to be disposed of in any other way. It was evident that the idea of disposal through dilution must carry with it prompt and satisfactory dispersion, and, unless some more effective means could be found for distributing the sewage than now exists, the full capacity of the water to absorb the sewage could not be realized.

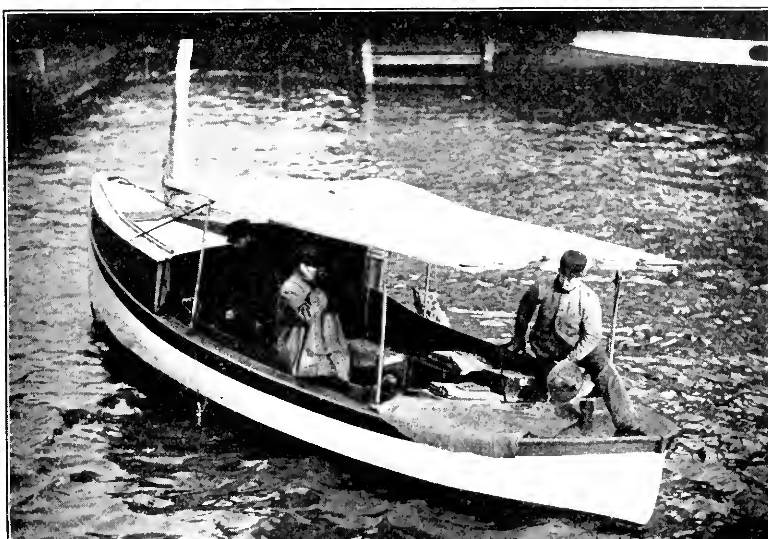

FIG. 4. ONE OF THE FLOATING LABORATORIES.

The problem of how much sewage the waters could absorb was not to be solved by mathematics, nor by chemistry, nor by reference to the known capacity of inland streams, nor by means of laboratory experiments, but by a judicious consideration of these data. It was necessary to observe what the waters were receiving in different parts of the harbor and how they behaved under their sewage loads. To obtain this information, boats were fitted out to carry engineers, chemists and biologists with the necessary apparatus for accurate observation. They visited

all parts of the harbor at all seasons of the year and at all stages of the tide. One of these floating laboratories went even further. When, during the course of its work, the Commission felt the need of information about the Boston and Metropolitan outlets which could not otherwise be obtained, it sent a boat to Boston harbor which spent about a month there.*

Disposal through Dilution.

The sewage which is discharged into New York harbor is disposed of principally by natural phenomena which the Commission has collectively termed digestion. There is nothing unusual about this process, it being commonly met with and utilized on land. All organic matter must pass through it eventually. It is, in fact, nature's universal way of resolving offensive and potentially offensive wastes into harmless and often useful substances.

Dilution, although indispensable for the avoidance of nuisance, is only one step in the process. Biological changes of profound significance are at the center. The solids must be liquefied and the liquids oxidized before the disposal is complete. The proper function of dilution in twofold. It must separate the sewage particles so that the living organisms which change the organic to inorganic matter may have the opportunity they require to carry on their work, and it must supply the needed oxygen. If this opportunity is not given, offensive conditions result. When too much sewage is put upon farms or filters, that is, when the load of organic matter becomes too great for the digestive capacity of the land receiving it, the land is said to be sewage sick, and it is appropriate to speak of water in the same way. Parts of New York harbor are sewage sick.

For digestion to proceed satisfactorily, large quantities of oxygen are required, and it is obtained from that which the water contains and can absorb from the atmosphere. Those sewage ingredients which cannot promptly be consumed float about or are deposited. In New York harbor deposits of sewage sludge exist wherever the currents are sufficiently slow to permit them to form. They putrefy and give off products which make

* This information related to the amount of dissolved oxygen in the water.

large demands upon the dissolved oxygen in the overlying water.

The water of the harbor is so polluted and darkened by sewage as to be unsuitable for bathing and for the taking of

FIG. 5. POINTS WHERE DREDGINGS HAVE BEEN COLLECTED FOR ANALYSIS. THE THOROUGHNESS WITH WHICH THE TERRITORY HAS BEEN COVERED ILLUSTRATES THE COMPLETENESS WITH WHICH ALL THE ANALYTICAL WORK HAS BEEN DONE.

shellfish for food. The turbid streams from the sewers discolor the water for long distances, especially throughout the inner harbor where fields of sewage and collections of excrement and other solid particles of sewage origin exist. Effervescence occurs among the docks for a large part of the year; the Harlem River, near Hell Gate, appears at some stages of the tide to be composed exclusively of sewage, and in the Gowanus and Wallabout canals and Newton Creek the water is black. From the Narrows seaward, and from Hell Gate to Long Island Sound, the conditions are materially better.

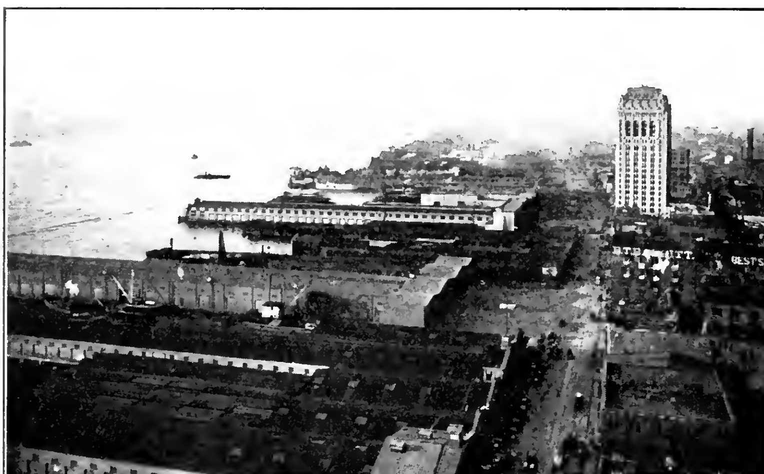

FIG. 6. MANHATTAN WATER FRONT. THE SEWAGE NOW DISCHARGES EITHER AT THE SHORE LINE OR BENEATH THE PIERS. THE SLIPS BETWEEN THE PIERS HAVE BEEN DESCRIBED AS SEWAGE TRAPS.

The Commission has laid emphasis upon dissolved oxygen as an index of the relative intensity of pollution and has made comparatively few of the complicated nitrogen determinations which are usual in water analyses. The oxygen found in the water shows what the sewage has left of that which was originally present plus that which the water has absorbed from the air. On incubating the samples more dissolved oxygen, and sometimes very much more, disappears.

In the summer of 1913 the amount of oxygen found in the lower East River averaged about 43 per cent. of the amount required to saturate water of the temperature and salinity of the samples. On more than one occasion, the best water procurable in this part of the harbor held only 13 per cent. of dissolved oxygen. Samples of the polluted water lost from 33 to 45 per cent. of the dissolved oxygen initially present when incubated at room temperature for seven days, while uncontaminated sea water lost none. Experiments showed that the rate at which the dissolved oxygen was consumed depended upon the amount of oxygen which was originally present, an abundant supply facilitating oxidation.

It is impossible to say with great accuracy how many pounds of oxygen one million gallons of sewage will require in order that the putrefiable ingredients may be rendered inert, the two ways of approaching this subject, by analysis and by incubation tests, being too artificial to show accurately what can reasonably be expected in practice. On incubation, mixtures composed of 5 per cent. of raw sewage and 95 per cent. of well aërated water from the lower East River, consumed about 6 cu. cm. of dissolved oxygen per liter. This corresponds to 1 428 lb. of oxygen per million gallons of raw sewage. Assuming that the Metropolitan Sewerage District will produce 770 000 000 gal. of sewage per twenty-four hours in 1915, it appears that 527 tons of oxygen will be required to oxidize it.

Form of Administration Needed.

Referring to the first question raised by the legislature, the Commission does not consider it possible to protect the harbor by inter-city agreement. There are too many cities, and their interests are too diverse. In the Commission's opinion, the ideal procedure would be to create a sewerage district in order properly to provide for the disposal of the wastes, the most desirable limits for the district including a territory of about 700 sq. miles. The area is well defined by topographical limits and is of about equal extent in New York and New Jersey. Practical considerations make it unlikely that an interstate metropolitan sewerage district will be established, at least for many years to

come. Meanwhile, the Commission considers that the city of New York should proceed with the construction of such works as are needed, whether a metropolitan sewerage district is created or not, for by disposing of its sewage in a proper manner, New York will place itself in position to require that its neighbors shall do likewise.

In the opinion of the Metropolitan Sewerage Commission, the construction of the works required by New York should be placed in the hands of a central commission representing that city. At the present time, the local sewerage systems are, in conformity with the city charter, designed and built under the Borough presidents by bureaus of the offices of the Commissioners of Public Works. The Metropolitan Sewerage Commission has not recommended that there shall be any interference with the functions or prerogatives of these constituted officials. The Commission is not concerned so much with local as with general sewers. Its interest in general sewers lies in the means which they afford for conveying the sewage collected by the local systems to suitable points where it may be disposed of in a sanitary manner.

The Commission is of opinion that special provision of an administrative character is required for the construction of the main drainage and disposal works. In New York, as elsewhere, engineering projects of unusual magnitude are usually provided for in this way, examples being furnished by the Croton aqueduct, the rapid transit subway and the additional water supply from the Catskill Mountains. By recommending the termination of their official existence with the making of their final report, which will probably appear by May, 1914, the Metropolitan Sewerage Commission has eliminated itself from consideration as a constructive body.

General Principles Governing the Main Drainage Plans.

A fundamental principle which has guided the Commission in its work of laying out a main drainage system for New York has been that the digestive capacity of the harbor for sewage should be utilized as far as considerations of health and public welfare permit. It is recognized that the digestive capacity is a

great asset which, if utilized intelligently, may result in large economies. At the same time, it must not be forgotten that the harbor waters represent a great asset for health and convenience and that its value in this preëminently important direction may be greatly impaired unless it is preserved in accordance with a wise and far-seeing policy. This raises the question, — To what extent must the harbor be protected from sewage?

In order to arrive at the broadest and most reliable opinion possible as to the degree of cleanness which is necessary and sufficient for the water, the Commission sought the advice of many experts in sanitary engineering, chemistry, biology, hygiene and public health administration, and a definite standard of cleanness was formulated. The Commission advised the city to adopt this standard as a guide, and apply it, with reasonable regard to the modifying influence of local circumstances, in the preparation of all drainage plans. The standard takes account of the condition of the water as observed by the senses and of the oxygen content. It is, briefly stated, as follows.*

1. Garbage, offal or solid matter recognizable as of sewage origin shall not be visible in any of the harbor waters.

2. Marked discoloration or turbidity, effervescence, oily sleek, odor or deposits, due to sewage or trade wastes, shall not occur except perhaps in the immediate vicinity of sewer outfalls, and then only to such an extent and in such places as may be permitted by the authority having jurisdiction over the sanitary condition of the harbor.

3. The discharge of sewage shall not materially contribute to the formation of deposits injurious to navigation.

4. Except in the immediate vicinity of docks and piers and sewer outfalls, the dissolved oxygen in the water shall not fall below 3.0 cu. cm. per liter. With 60 per cent. of sea water and 40 per cent. of land water and at the extreme summer temperature of 80 degrees F., 3.0 cu. cm. of oxygen per liter corresponds to 58 per cent. of saturation. Near docks and piers there should always be sufficient oxygen in the water to prevent nuisance from odors.

* Report, Metropolitan Sewerage Commission, August, 1912, p. 70.

5. The quality of the water at points suitable for bathing and oyster culture should conform substantially as to bacterial purity to a drinking water standard. It is not practicable to maintain so high a standard in any part of the harbor north of the Narrows, or in the Arthur Kill.

There has been no criticism of this standard except as to the oxygen. Some have thought the restriction too low and others have thought it too high.

Another fundamental principle which has guided the Commission in making its designs has been that, as far as possible, only such works as were needed for the near future should be built at once. Provision should be made for extensions and perfections in the scheme of protection as the requirements of the future indicate. The Commission does not think it possible to see very far into the future. Many conditions and certainly sanitary standards will change. The plan of main drainage should be one which can give greater protection to the water as it becomes necessary. The year 1960 is the ultimate date for which the Commission has thought it reasonably safe to make any definite plans.

With reference to the second question propounded by the legislature, that is, the best methods of collecting and disposing of the sewage, the Commission's answer in condensed form is, — Intercepting and collecting sewers leading to central points and treatment works in which the sewage can be purified to a greater or less degree, depending upon the facility with which the effluent can then be discharged into the neighboring waters without offense. The number of central points should be large in order that the sewage burden may be well distributed and yet not too large to permit efficient and economical maintenance. Since some parts of the harbor can take more sewage than other parts, the outlets should be placed in those situations where the load can best be carried. To facilitate diffusion, the sewage should, in many cases, be discharged at the bottom of the main tidal channels.

The methods of treatment available for the sewage are restricted by the natural conditions of land and water, and by the densities of populations. Practically the whole city is

occupied for residence and business purposes. The least thickly settled areas and the cheapest land are unsuitably located for sewage disposal plants. In those localities where the greatest quantities of sewage are produced, the cost of land is exceedingly high. The distances to low priced land and to the open sea are great. Various plans for taking all the sewage to a single point for disposal were considered, but all appeared too costly.*

The most effective means of purifying the sewage which the Commission considers it permissible to locate in the built-up sections of the city is sedimentation. There is likelihood of odor from more effective processes. Perhaps chemical precipitation, which the Commission regards more as a form of sedimentation than as a distinctly separate process, would be feasible in some instances where plain sedimentation would not sufficiently prepare the sewage for discharge. In the outlying areas, sprinkling filters could, under some circumstances, be employed. The least treatment which any sewage should receive is screening, and all the sewage of the city should at least be screened.

When the Commission reached this decision, the problem resolved itself largely into one of locating screens and settling basins in the most advantageous ways for economy and efficiency and of considering their probable effect upon the harbor. If these processes would not be sufficient or their cost excessive, it would be necessary to consider the removal of some of the sewage to a distant point for disposal.

For the purpose of studying what it was practicable to do in the way of disposing of the sewage locally, the city was separated into four divisions, the boundaries of which corresponded approximately to the boundaries of the principal natural drainage areas which were tributary to the most important parts of the harbor. They take their names from these waters and are consequently easy to locate.†

The Jamaica Bay Division includes all the territory which is naturally tributary to Jamaica Bay. The Upper East River and Harlem Division contains the territory in the boroughs of Manhattan, the Bronx and Queens, whose drainage is naturally

*Preliminary Report No. 1, Metropolitan Sewerage Commission, September, 1911.
†Preliminary Report No. II, Metropolitan Sewerage Commission, November, 1911.

tributary to the upper East River and Harlem River. The Lower Hudson, Lower East River and Bay Division includes that part of Manhattan which is tributary to the lower East River and Hudson River and that part of Brooklyn which is tributary to the lower East River and upper New York Bay. The Richmond Division takes in that part of the borough of

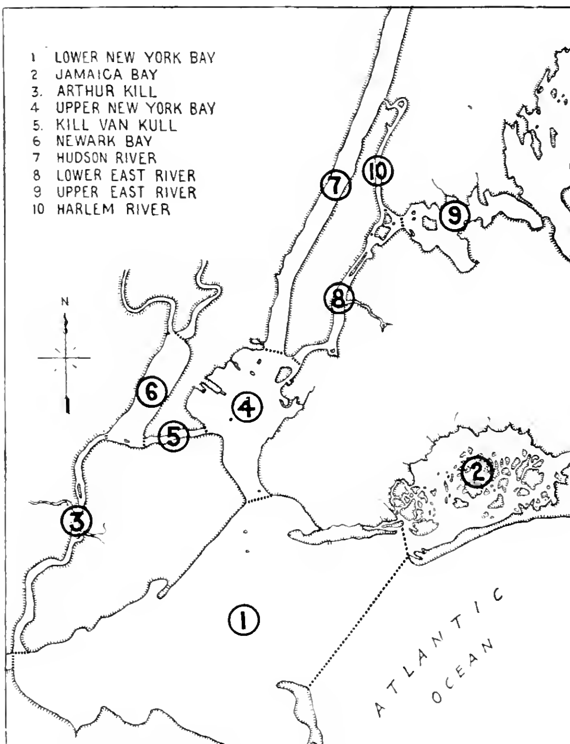

FIG. 7. THE MAIN DIVISIONS OF NEW YORK HARBOR.

Richmond whose drainage naturally flows to the Kill van Kull and upper New York Bay. These four large divisions have been separated into many subdivisions, which have been given numbers or names according to the ease with which their location can be recognized.

It was at first thought that by caring for the sewage of the more outlying parts of the city in a thorough manner, the waters in the inner harbor could be kept clean enough to assimilate all the screened or settled sewage which was there produced. The work ot planning was therefore begun with the Harlem and Upper East River Division and Jamaica Bay Division, after which the Richmond Division was taken up. The Lower Hudson, Lower East River and Bay Division was left to the last. It eventually appeared that no amount of treatment which could be given the sewage in the distant areas would secure to the waters of the inner harbor a capacity sufficient to deal with the sewage there produced even after this sewage had been given such treatment by screens and settling basins as could be provided. The improvement would not be sufficient, for the local load would still be too great.

The capacity of screens was taken at 15 per cent. for the removal of the suspended matter and 10 per cent. for the organic matter. Sedimentation was assumed to be capable of removing 60 per cent. of the suspended matter and 30 per cent. of the organic matter, and chemical precipitation was thought capable of removing 85 per cent. of the suspended matter and 50 per cent. of the organic matter. These percentages, generally accepted by engineers, do not, unfortunately, tell the whole story. They are based upon laboratory methods of measurement and give no accurate idea of the reduction in the deoxygenating properties which are produced by the processes to which they refer. The solid matters removed by screens and settling basins are not, for the most part, such as are capable of making an immediate or early demand upon the oxygen, it being the colloidal matter and the liquid part of sewage which do this and render the water turbid and greasy. Screens can remove the particles which are easily recognizable as of sewage origin and settling basins can take out about one-half of the solids which are capable of forming sludge, but it is doubtful if the more efficient of these processes is capable of reducing by more than 25 per cent. the amount ot oxygen which the organic matter requires from the water into which it is discharged. It is the Commission's opinion that none of these processes can sufficiently

improve the sewage naturally tributary to the lower East River to permit it to be discharged into these waters.

In a preliminary report the Commission has suggested that most of the sewage naturally tributary to the lower East River

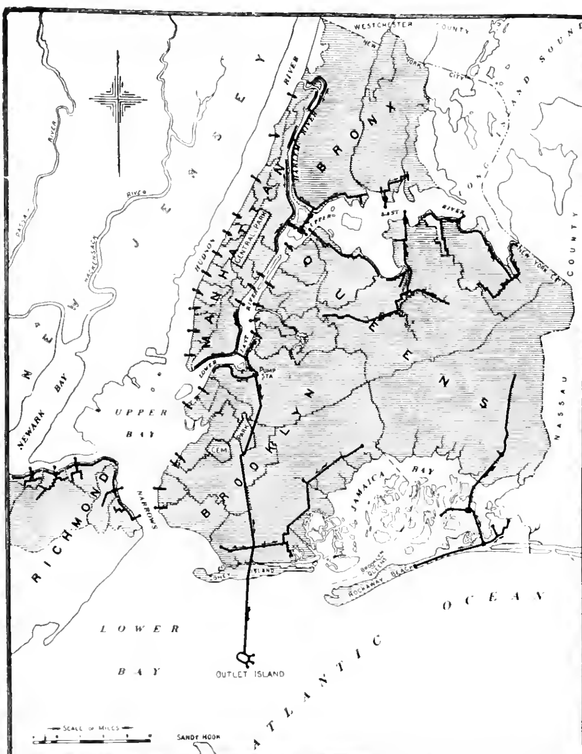

FIG. 8. GENERAL SKETCH OF MAIN DRAINAGE SYSTEM PROPOSED IN THE PRELIMINARY REPORTS OF THE COMMISSION.

be carried out to sea.* There are not many directions in which so large a quantity of sewage can be taken. It would be impracticable to carry it north into Westchester County, for the land there lies at too great an elevation; it would be impossible

* Preliminary Report No. VII, Metropolitan Sewerage Commission, February, 1913.

to take it west because the people of New Jersey would object to receiving it; and the idea of discharging it into the Hudson River cannot be entertained, for if this were done, that stream would become too heavily polluted, and sentimental considerations require that it shall not be made a receptacle for the sewage from other parts of the harbor. It would not be feasible to carry the sewage to Long Island Sound as the distance would be too great, the volume of water there available would be insufficient, the danger of polluting extensive shellfish beds would be too large, and the risk of contaminating the shores in the vicinity of villages and towns too imminent. The sewage could not be taken east on Long Island, unless to a distance of thirty or forty miles, for otherwise its disposal would be certain to cause serious injury to property already occupied for residential purposes or likely soon to become valuable for this purpose. Furthermore, opportunities for the disposal of the effluent of treatment works are lacking on Long Island, the north shore of which is deeply indented with bays and, for the most part, high and rocky, and the south shore of which is bordered with broad, shallow bays and marshy islands, where the flow of tidal water is relatively slight. Staten Island, to the south, contains several thousand acres of marshy land which might be built up and utilized for sewage disposal, but treatment works capable of purifying the sewage to such an extent as to permit the effluent to be discharged in that vicinity would be very costly and likely to produce an intolerable nuisance.

The Commission's suggestion is that about 203 000 000 gal. of dry-weather sewage, and approximately twice this amount at times of storm, be collected from those parts of Manhattan and Brooklyn which adjoin the lower East River and carried to an island to be constructed at the ocean entrance of the harbor about three miles from land. At this island the sewage should be passed through settling basins and discharged through several outlets at all stages of tide. It was at first estimated that the cost of this project would be about $20 000 000, but subsequent study has shown that this cost can be materially reduced.

There is no other part of the harbor comparable with the lower East River in size and importance, where the water is so polluted or where it should be kept so clean. Nowhere else in the metropolitan district can so much sewage be collected with such short intercepters, and no other measure of relief for the lower East River, no matter what its cost, could produce so much benefit. The results would be felt not only in the lower East River, but would extend to upper New York bay, the upper East River and to the Harlem. These are localities where, in spite of every endeavor, the pollution is certain to increase very greatly as time proceeds.

This project contemplates the ultimate digestion of the organic matter of the sewage by the sea water. Responsibility for the disposal of the sewage cannot cease until all the ingredients are rendered harmless and inert. It is important that the sewage shall not flow from the outlets as a coherent mass and that none of its elements shall be carried to the inner harbor or find their way, under the influence of wind or tide, to the shore. Accumulations of solid matter injurious to navigation must not be permitted to occur, nor must odors or flies or other objectionable features too commonly associated with sewage disposal works exist to an extent which will seriously mar the natural attractiveness and healthfulness of that part of the ocean where the outlet is located. The sewage will have a strong avidity for oxygen and will be mineralized by the oxygen-saturated sea water with which it comes in contact. The great amount of water available at the point of outfall will supply an abundant capacity to digest the effluent.

If at any time in the future it becomes desirable to more completely purify the sewage, no more favorable location for the necessary works can be found in the metropolitan district than this proposed artificial island. Owing to the shallowness of the water and the ease with which filling can be obtained, land can be made here cheaper than it can be bought on shore at any point not more distant from the City Hall.

In addition to the sewage from the lower East River section, it may be feasible and desirable to send the sewage of the western Jamaica Bay subdivision to the island for disposal. This would

make it unnecessary to construct treatment works at Barren Island as proposed.

There are various ways in which the sewage can be collected. One method may be described by way of illustration. The dry-weather sewage can be collected by marginal sewers to a central point in each subdivision and there passed through grit chambers and screens. Passing beneath each central collecting point will be a deep-lying intercepting sewer which will receive the sewage after it passes through the screens and grit chambers. Storm water in excess of twice the dry-weather flow will pass by overflows at each outlet directly to the river. Each central collecting point will have storm overflows, regulators and tide gates so arranged as to discharge directly into the neighboring waters the excess flow of sewage during periods of rainfall. The intercepters are intended to be large enough to accommodate twice the mean rate of flow during periods of dry weather. The maximum rate of dry-weather flow is assumed to be about one and one-half times the average rate. This will permit the intercepter to carry off some of the first flush of storm water even if it reaches the plant during the hour of maximum sewage production.

The marginal conduits required to collect the sewage from the present sewers to the central point in each subdivision will lie as close to the surface of the ground as physical conditions permit. The intercepters will be situated at a considerable depth and be so located as to avoid, as far as possible, difficulties of construction. It will probably be necessary to construct them by shield tunneling. In making the plans and estimates, careful attention has been given to the information available concerning the geology of the territory passed through as determined by borings.

A siphon will be required to carry the sewage from Manhattan to Brooklyn beneath the lower East River. The point selected for the crossing is at a narrow part of the river where solid rock may be anticipated. The siphon which will be required to take the sewage produced in 1915 should have a diameter of 8 ft. 9 in. It will be 110 ft. beneath the surface of mean low water, will be 2 300 ft. long and extend from Cor-

lears Hook to South 8th Street. When the North Manhattan intercepter is extended so as to take more sewage it will be necessary to build a second siphon which can be laid parallel to the first. It is desirable that the siphons needed at first shall not be too large, in order that the velocity of flow may be sufficient to prevent deposits taking place.

The sewage collected by gravity at the general pumping station, amounting to about 200 000 000 gal. a day, will have been passed through grit chambers and screens and will be in a reasonably fresh condition. Pumps will be required to raise the sewage from an elevation of about 27 below mean tide and force it under a head of about 45 ft. to the artificial island, a distance of about 11.8 miles.

The tunnel to the island will be 14 ft. in diameter and constructed at a depth of about 60 ft. through sand. It will be possible to construct the tunnel with two headings, one from the shore and one from the island, the two meeting and being properly joined.

The location of the island has been carefully chosen with reference to economy of construction, resistance to the destructive influences of tidal currents and storms, freedom of obstruction to the flow of tidal water in and out of the harbor and absence of sanitary objections. It lies north of Sandy Hook and south of Coney Island. The water within a mile from the island in all directions is from 7 to 40 ft. in depth, the average being about 20 ft. at mean low tide.

In plan the island is approximately rectangular, the seaward side being rounded and the area being about 20 acres. This can be extended as required. The outer face of the island will be a wall of riprap composed of large stone laid upon the hard sandy bottom. It is expected that some settlement will occur, due to the water cutting sand away from under the stone, but when sufficient riprap has been placed to stop this action, no more settlement is to be expected. The main bulk of the island will be composed of sand supplied by a suction dredge from the bottom of the sea in the vicinity.

The height of the island above mean low water will be about 18 ft. The length will be 1 300 ft. and the width 1 000

ft. The side of the riprap wall which is exposed to the sea will have a slope of 1 vertical on 3 horizontal and the other sides will have a slope of about 1 on 2. The cost of constructing the island has been estimated at about $615 000.

The landward side of the island will be provided with a quay wall for the accommodation of vessels engaged in taking supplies and other materials to and from the island. Shelter from the sea will be provided by a breakwater which will enclose a small harbor.

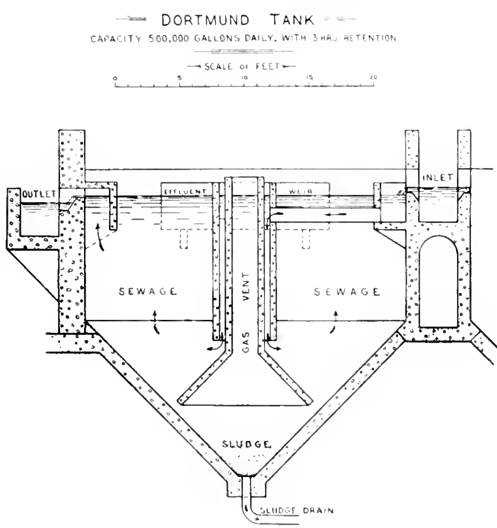

FIG. 9. SKETCH OF A DORTMUND TANK WITH PROVISION FOR THE ESCAPE OF SUCH GAS AS MAY UNAVOIDABLY BE PRODUCED.

The island will contain settling tanks in which the sewage will have an opportunity to deposit its solid matters during a period of about two hours. These tanks will be of modified Dortmund tank construction, somewhat similar to those recently constructed at Toronto, Canada. Provision will be made for treating the sewage with a coagulant before passing it into the tanks if necessary. The material which settles out will be carried to sea and dumped.

After treatment, the sewage will be discharged through a number of radial outlets on the seaward side of the island. If desirable, it will be feasible to pump sea water into the sewage and provide for the mixture of the two before the discharge takes place. Such admixture would facilitate the immediate diffusion of the sewage in the sea water, but the active agitation and free movement of the great volume of water in the vicinity

of the island will probably make the preliminary admixture of sea water and sewage unnecessary.

This project will require the construction of about 5.3 miles of marginal sewers in Manhattan and Brooklyn and about an equal length of intercepters in these two boroughs. The siphon from Manhattan to Brooklyn will be a little less than a half mile long. The main from the pumping station to the island will be about 13 miles long. If the Jamaica Bay sewage is brought to the island, about 2 miles of collectors and 7 miles of intercepters will be required in addition.

The studies which were first made indicated that the total cost of construction would be about $22 874 000, including $4 072 000 for the Jamaica Bay Division. The fixed charges, including sinking fund and interest, would be about $1 157 000, allowing $206 000 for the Jamaica Bay Division. The total maintenance and fixed charges would amount to about $1 803 - 000, including $286 000 chargeable to the Jamaica Bay Division.

The rest of the sewage produced in the Lower Hudson, Lower East River and Bay Division would be discharged locally through submerged outlets. Such study as has been given to the subject thus far indicates that there would be about twenty-five central points where the sewage would be passed through screens.

Scarcely second in size and interest to the ocean island project, which has attracted more popular attention than any other feature of the Commission's plans, is the project for the relief of the Harlem. This scheme follows more usual lines, although there is no single feature connected with the ocean island project which is unprecedented. The Harlem project consists of intercepters running along the shores of the river, skirting two sides of the Hell Gate region, extending along the north shore of the East River from Hunt's Point and converging to a central point on Ward's Island which belongs to the city, being used in part for charitable purposes and being in part vacant. At the island the sewage would pass through settling basins, presumably of the Dortmund type, and the effluent would be discharged through outlets extending to the bottom of one of the deepest, largest and most swiftly flowing

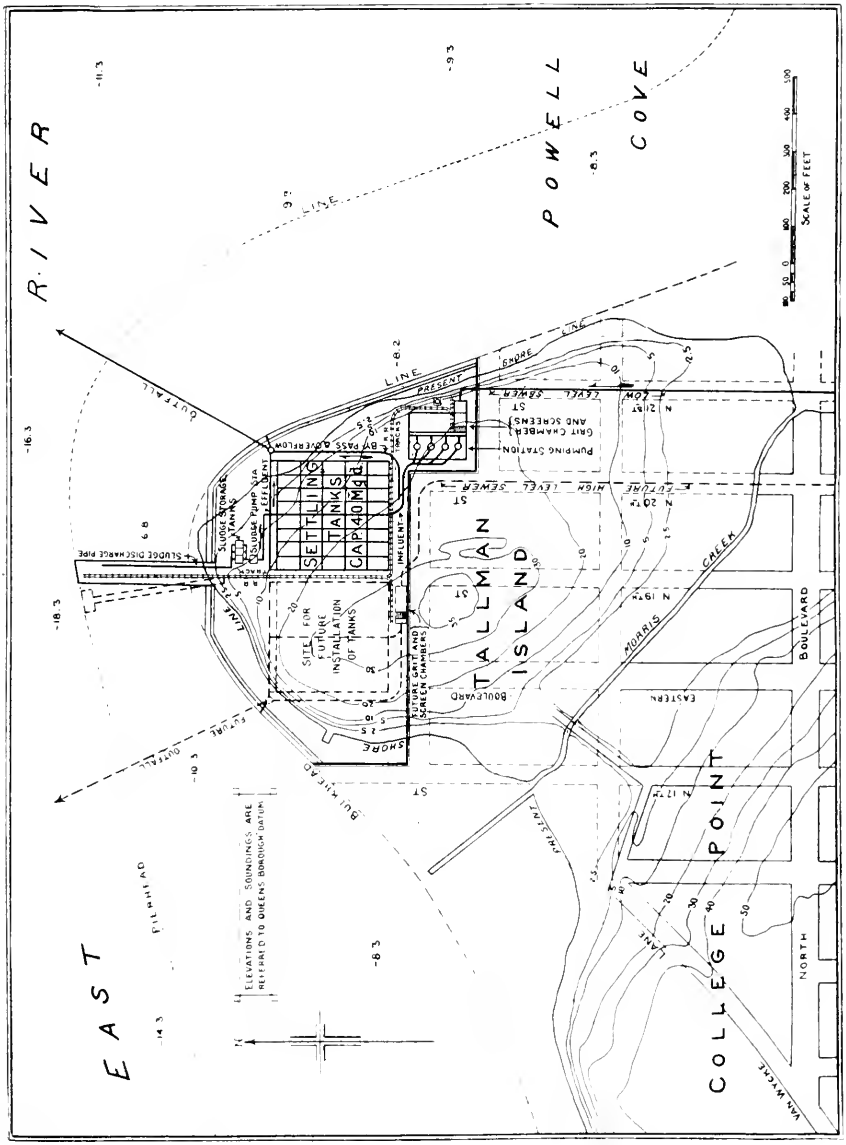

FIG. 10. GENERAL PLAN OF THE SETTLING PLANT AND ITS APPURTENANCES PROPOSED FOR TALLMAN'S ISLAND IN NORTHERN QUEENS. SIMILAR WORKS HAVE BEEN SUGGESTED FOR WARD'S ISLAND AT HELL GATE AND CLASSON POINT IN EASTERN BRONX.

streams in Hell Gate. Diffusion should be prompt and thorough at this point.

The Dortmund type is preferred to any other kind of settling tank because of its compactness, ease of operation and absence of odor when the sludge is being taken out. It has not seemed to the Commission that two-story tanks which provide for the digestion of sludge are well adapted to the conditions to be met with in New York, unless in exceptional localities, as the sludge problem is not difficult to deal with here, the easy method of disposing of sludge by transportation to sea being available.

The main drainage system tributary to Ward's Island is designed to carry 405 million gallons. It is estimated that, by the year 1940, 302 million gallons of sewage will be produced. It has been suggested that the treatment works should have a capacity of not less than 200 million gallons to begin with, and this is the basis of the estimate of cost for them. The cost of construction, including engineering, would be about $9 814 000. The cost of maintenance, including fixed charges, is taken at $701 000 per year. The works would not be completely built at once, but would be constructed gradually.

For the protection of the rest of the upper East River, the Commission has proposed works which will collect most of the sewage which is tributary to this part of the harbor to four of the many long points of land which extend like fingers from the main shores out into the tidal channel which runs in a straight line from Hell Gate to the sound. Between these points are deeply indented shallow bays, at the heads of which are extensive meadow lands which are flooded at spring tides, which must be kept clean. The opportunities for disposing of sewage, except by carrying it out to the points mentioned, are few. The population on the drainage areas is rapidly increasing and New York's future growth will be largely in this outlying territory.

The Commission's plans for the upper East River require that the sewage shall be brought to the disposal points by collectors running inland and intercepters extending around the water front. Some of the collectors will have rather flat grades, but their sizes are large and comparatively little pumping will

be required except at the disposal works. Where practicable, provision has been made for high-level collection to supplement the low-level main lines. The method of disposal proposed is sedimentation followed by discharge of the effluent into the deep tidal streams near at hand. In course of time, perhaps chemical precipitation, or some better process not yet invented, may be desirable. In two cases screening is all that is considered necessary for the small volume of sewage which will be produced for many years to come.

In all cases provision of land should be made for such processes as may be needed for the future. The sewage from that part of the Upper East River and Harlem Division not tributary to the Ward's Island plant would probably amount to about 85 million gallons by 1940. The total cost of the works proposed for this entire division, including the Harlem and Ward's Island project, is $13 398 000.

The Jamaica Bay Division has presented a unique problem. The population during the summer months is dense and growing and the bay itself is extensive in area, very shallow and used principally for pleasure and recreation purposes. It is proposed by the Commission that intercepting sewers shall ultimately be provided to collect the sewage from around practically the entire bay and deliver it at two centrally located points, one near the ocean entrance and one at the inner end. In case the ocean island works are built for the relief of the lower East River, the sewage from the western part of Jamaica Bay can be most economically carried to that place for disposal.

In case no sewage is taken from this Division to the ocean island, the works at the ends of Jamaica Bay would include settling basins, sprinkling filters and supplementary sedimentation tanks. Perhaps sterilization would also be required, as the object would be to purify the sewage to the utmost extent practicable. As an alternative for the eastern part of this division, it has been suggested that the sewage be discharged, after settlement, from a submerged outlet located in the open ocean some distance from shore. Inasmuch as the beaches in this vicinity are densely crowded in summer with bathers and other recreation and health seekers, it would seem that any

risk of pollution should be scrupulously avoided. The necessity for keeping the waters clean is the greater since the inner harbor must be utilized to a large extent for sewage and cannot be kept safe for bathing.

The sewage from about 53 700 acres would be provided for in the Jamaica Bay Division, the population served would be about 1 415 700, and the volume of sewage, 204 million gallons daily by 1950. The cost of the works is estimated at $14 213 000, and the annual charges, including interest at 4½ per cent. and sinking fund for fifty years, $1 204 000. The works would be expected to reach their capacity in about forty years. If the artificial island is built for the relief of the lower East River, a large saving in the cost of the works necessary for the western part of Jamaica Bay could be effected.

The works proposed for the Richmond Division, which is a hilly country with rather steep shores, comprise screens and grit chambers and it has been proposed that five centrally located plants be installed. The total quantity of sewage is small. After treatment, the sewage will be discharged at the bottom of the Kill van Kull and upper bay at a sufficient distance from shore to insure satisfactory diffusion.

The sizes of the main sewers to be provided for in the Richmond Division were not based upon populations estimated for a given year, but upon densities on the tributary areas which were considered probable when those areas reached approximately their ultimate development. The total cost of construction need not be very large, as the collectors and intercepters would be short and the saving effected by cutting down the capacities materially would not be very great. The total population was 58 939 in 1910 and is taken at 633 620 in the estimates, and the total quantity of sewage assumed is 86 million gallons per day. The ultimate density of population is not expected to exceed 150 per acre in any subdivision. The flow assumed for the first installation of the works was 22 million gallons. The total estimated cost of construction, including 15 per cent. for engineering and contingencies, is $841 000, and the yearly cost with fixed charges is $69 540 for the whole division.

Conclusion.

It will be seen from this brief review that the Commission places great importance upon utilizing the digestive capacity of the harbor waters. In seeking to solve New York's sewage problem, it has taken the position that the harbor must always be regarded as polluted from the standpoint of drinking water and bathing and shellfish culture, but that there is no warrant for such excessive pollution as now exists. It was believed that the requirements of the future, so far as cleanness is concerned, will be more exacting than they now are and, by providing a plan which will afford the minimum protection needed now and which can be made more effective later, the Commission feels that it is following a prudent and conservative course.

So far as correcting present conditions is concerned, the Commission has been careful not to recommend works which will merely transfer a nuisance from one locality to another. The aim has been to propose methods which are as free from objectionable features as practicable.

To a large extent the works can be built progressively, and in this respect the recommendations represent a program as well as a plan. By adopting the principle of gradual construction in accordance with a definite general plan, protection to the harbor can be afforded as the need of protection is recognized, the cost can be distributed over a long period of years and the works can be made increasingly efficient.

In the choice of methods the Commission feels strongly the restrictions which good engineering practice places upon them. It has felt the need of more intensive and less offensive methods than have thus far proved successful in other cities. It is by no means impossible that more suitable methods than are known to-day will be developed in the future, but the Commission thinks that the improvements which can confidently be expected will be more in the nature of refinements than revolutionary in character.

The members of the Commission since 1908 have been: George A. Soper, M. Am. Soc. C. E., President; James H. Furetes, M. Am. Soc. C. E., Secretary; H. deB. Parsons,

M. Am. Soc. C. E.; Charles Sooysmith, M. Am. Soc. C. E.; and Linsly R. Williams, M.D.

The Commission has had a small but efficient staff of assistants, the personnel of which has varied from time to time according to the work to be done. There has been no chief engineer, all the scientific, technical and clerical work being under the immediate direction of the president, who has acted as the executive member of the board.

It has been the policy of the Commission to call well-known experts in various fields for consultation and reports upon the larger problems which have had to be solved. To a considerable extent the Commission's recommendations, therefore, embody not only such authority as may attach to the personnel continuously connected with the work, but a large amount of opinion from other experience and other points of view.

As already stated in this paper, such works as have been proposed represent the opinion of the Commission at the time and with the information available when the reports embodying the projects were issued. It has not seemed proper in preparing this paper to describe any of the opinions or recommendations which the Commission has not yet officially made. The last report recommending a project was issued in February, 1913. Since then a large amount of attention has been given to reconsidering and coördinating the various projects. The final report of the Commission, which is now in preparation, will describe the results of these matured studies.

Vol I FEBRUARY, 1914 No. 2

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

THE FALL RIVER BRIDGE.

BY JAMES W. ROLLINS, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented December 17, 1913.)

THE Fall River Bridge, or, properly named, the Brightman Street Bridge, was built across the Taunton Great River at Fall River, Mass., at a point about one thousand feet upstream from the Slade's Ferry bridge. It is for a highway only, has a 50 ft. roadway with two sidewalks of 10 ft. each, and was built with three spans of 200 ft. each, two spans of 100 ft. each, and a double leaf Scherzer rolling lift draw span with an opening of 100 ft.

The contract plan for the piers was merely a cross-section of the river showing the bottom and the locations and sizes of the piers, with no details whatever.

The specifications provided that "Piers 1, 2 and 3 shall be placed on foundations prepared in firm, solid ledge. Pier 4 shall be built on a foundation of piles cut off 40 ft. below low water; Pier 5 on piles cut off 15 ft. below low water."

It was evident from an examination of the river section and considering the requirements of the specifications, that Piers 2 and 3 must be on pneumatic foundations, and rock was 60 ft. more or less below low water. After consultation with the engineer, he decided to build Piers 1, 4 and 5 on pile foundations, and Piers 2 and 3 on pneumatic foundations. Working plans

NOTE. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before April 15, 1914, for publication in a subsequent number of the JOURNAL.

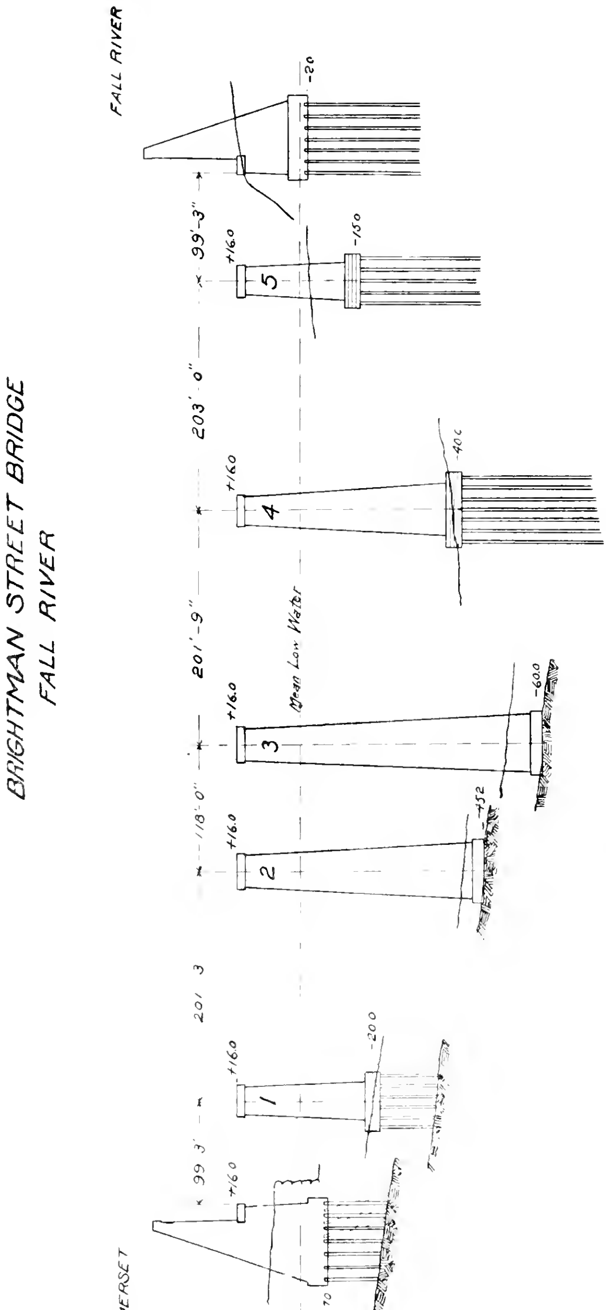

FIG. 1. CONTRACT PLAN FOR THE FALL RIVER BRIDGE.

were made accordingly for the well-known method of open caisson and heavy wooden grillages for the pile piers.

For each caisson a timber grillage was built of 12-in. by 12-in. yellow pine timber about 4 ft. larger each way than the masonry foundation, with the first course longitudinal, the second at 45 degrees to the first course, the third at right angles to the second course and the fourth at right angles to the first. The timbers are put together with 1-in. by 20-in. drift bolts at

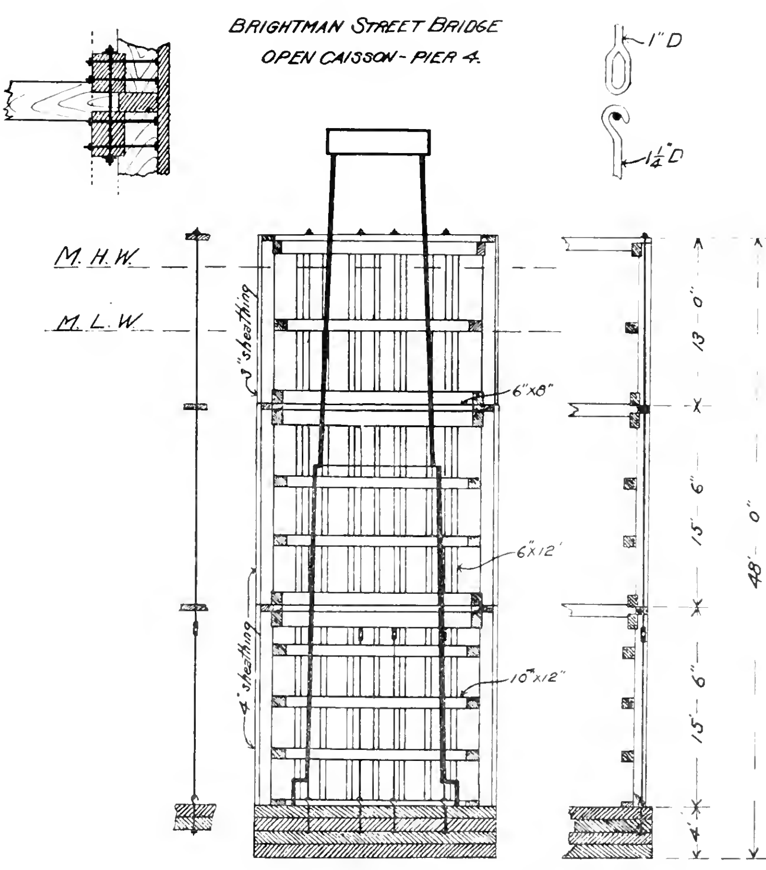

FIG. 2. SECTION OF CAISSON, SHOWING HOOKS AND LOOPED RODS.

each intersection. These timbers were sized one way to make the courses of even thickness.

Through the two top courses hook bolts of $1\frac{1}{4}$-in. iron were fastened every 4 ft., and so shaped at the tops that the loops in the ends of the vertical rods holding the sides of caisson to the bottom would drop clear of the hooks when the rods were unfastened and driven down after the masonry was completed.

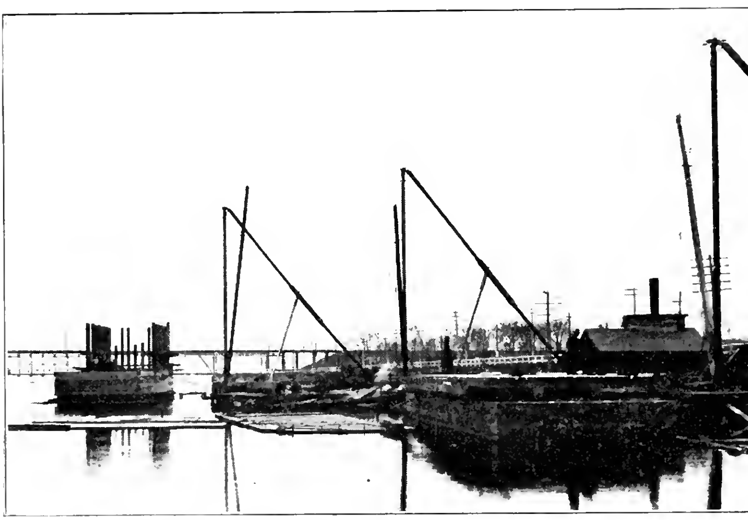

Fig. 3. View of Caisson after Launching.

The top course of the grillage was then thoroughly calked in both horizontal and end joints with oakum and pitch, and the grillage was launched, it having been built on timber "launching ways," and floated to the derrick or lighter which was to put up the sides.

The sides were built of 6-in. by 12-in. vertical posts, spaced 24 in. center to center, and planked with 3-in. planking, or 4-in., according to depth of water, and were from 16 to 24 ft. high, depending on the depth of water and the size of the caisson, it not being desirable to have more than one joint in the sides. The height of the sides was limited by the weight which could

reasonably be handled by the lighter or derrick available, from 20 to 30 tons in practice.

On top of the 6-in. by 12-in. vertical posts were spiked 6-in. by 12-in. caps, and $1\frac{1}{4}$-in. rods with nuts at the top ends and loops at the lower ends, with turn buckles, were placed with the loops over the hook bolts in the grillage, so holding the sides down firmly to the grillage. All the joints in the sides and ends were thoroughly calked.

The sides and ends were then thoroughly braced and X-braced, to keep the caisson in shape and to withstand the water pressure until the masonry was built. On the grillage with the side on it, the combination making a watertight box, was laid the masonry, beginning at the center and working towards the ends.

When this load of masonry sunk the box down in the water to within 4 ft. of the top, the second set of sides, made similar to the bottom set, were hoisted into place, the posts of the second set being fastened to the cap on the first and then calked tight and braced as before. This process was continued with the third and fourth sets of sides, until the bottom of the caisson as loaded floated one or two feet at high tide over the tops of the piles in the foundation it was to rest on.

Generally, pile dolphins are driven to keep caissons in position, but at Fall River the water was too deep, consequently heavy anchors consisting of 15-ton concrete mooring blocks were used to hold the caisson.

When lined up both ways by the engineers, the caisson being level, at high water the caisson was scuttled by knocking out plugs previously put in below the water line and sunk upon the pile foundation in its true position.

Additional masonry was then laid as rapidly as posible to add to the weight in the caisson, but not to come above low water. If the masonry inside the caisson was below the water level outside when the caisson was sunk, the plugs were put back, calked, and then the water inside the caisson was pumped down below the masonry level.

At this time the lines and levels were again taken and the masonry trued up to its proper position, the bottom section built

when the caisson was afloat having been large enough to afford an offset of about 6 in. at the top, so giving room enough for a true adjustment for the pier above the water line. The masonry was then finished above high water.

As the masonry was built up the braces were taken out and the sides of the caisson maintained by short braces from them to the stone work. When the last side was in position, long rods from the top cap to the turnbuckle below the cap in the first set were substituted, one by one, for the short rod ends from the turnbuckle to the first cap, so that the entire flotation strain of the sides came upon these rods.

To release the sides, the top nuts were taken off and the rods driven down so that the loops in the lower ends were driven clear of the hook bolts in the grillage, so freeing the sides, which floated up when released and were used over again on other piers.

On account of the depth of water at the draw (about 60 ft.), and the small amount of earth covering the ledge, riprap was ordered deposited around the piles driven for fender, to hold them down and to help support them.

This bridge was built under an act of the Massachusetts legislature, by a "joint board" consisting of the Harbor and Land Commission, the Railroad Commission and the County Commissioners of Bristol County, forming a board of nine men. Mr. E. K. Turner was the engineer making plans and specifications and Mr. R. M. Berrian the engineer during construction, until his death in December, 1907, when Mr. Turner again took up the work and finished it, with Mr. R. F. Stoddard as resident engineer during the entire construction. Messrs. J. R. Worcester & Co. were the engineers for the steel work.

The general contract for the whole structure was given the Holbrook, Cabot & Rollins Corporation, of Boston, who sublet the steel work complete to the American Bridge Company of New York. The contract for the bridge complete was awarded in December, 1906, and work was begun at once. All masonry was built by October 1, 1907, and the steel work and approaches were finished and the bridge opened for traffic in the spring of 1908.

On July 20, 1911, the writer was told that one of the piers of the Fall River Bridge had settled and that the bridge had been closed to public travel and he was asked to go to Fall River the next day to meet the County Commissioners, to find out what had happened and what to do. At this meeting it was developed that Pier 4 had settled 2 ft. at the bridge seat level at the south end, about 8½ in. at the north end, and had moved upstream, to the *north*, some 12 in. and had also tipped 5 in. to the east.

Various theories were advanced as to the cause of the trouble, and at that time the writer held that the piles had been crippled

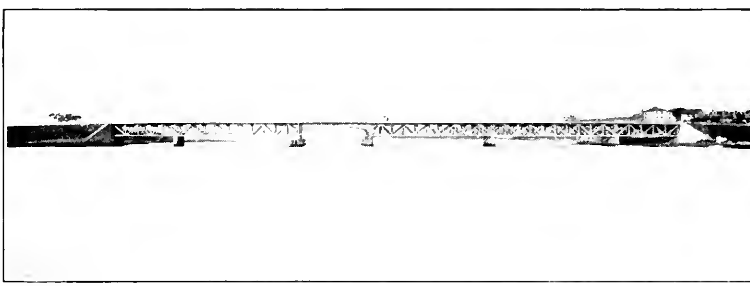

FIG. 4. THE COMPLETED BRIDGE.

in driving and had been broken off, as the bottom was almost a hard pan. The writer, having been in actual charge for the contractors, and having full knowledge of all details of construction, offered to investigate and report to the County Commissioners as to the cause of trouble. This offer was accepted and instructions given him "to do all necessary work to temporarily protect and preserve said bridge."

Divers went down and reported piles broken off, and the pier resting on them. Another diver of great experience was sent down, and reported in part that filling had been scoured out around the piles to a depth of 2 to 3 ft., so exposing the piles, many of which at the south end of the pier had been broken off at the ground line. He brought up a piece of one of these piles and reported that "this portion of the pile bears evidence of

the ravages of the teredo and has been so much eaten away that but little of the pile was left at the time of the breakage and will explain in large measure the cause of the pier's failure." This report was made on July 27, and was the first intimation of the true cause of the failure, viz., " the ravages of the teredo." It was common knowledge that the teredo was plentiful in Taunton Great River and was very active on the wooden structures in that vicinity, but no one thought of the possibility of its working 45 ft. below water line.

The first conclusion was that the pier was resting on the crippled piles and on solid bottom, careful observation having been made daily and no settlement having been noted. Plans were then made to jack the trusses up on each side of the pier and block them in their true line and grade, so as to open the bridge to traffic. In studying this plan it developed that the trusses weighed 500 000 lb. each for one span, and about 400 000 lb. for the other span, that there was no room on the pier to place jacks and nothing in the steel construction at the pier strong enough to hold the dead load of the bridge on the jacks.

Further study of conditions developed the great uncertainty of stresses and resistance to them. Pier 3 was tipped 4 in. to the east, i. e., along the line of the bridge, spans 4 and 5 were " butted " against each other on Pier 5, and span 5 was solid against the Fall River abutment; so that the stability of Pier 4 was uncertain if the load of span 4 was taken off. Consequently, to avoid the danger of losing span 4 should Pier 4 collapse, and also to provide means to jack that span up into its original position after repairing the pier, it was decided to drive piles under the panel point nearest to Pier 4, about 40 ft. away, and block up on these pile bents close enough to support span 4 should it settle further. The water at this point was 40 ft. deep and the bottom of the river was hard pan, so the heaviest piles obtainable, 60 ft. yellow pine with 8 in. tip, were driven in groups of 24 under each truss, using a pile hammer hung on leads suspended from the top chords of the trusses. This was very slow and difficult work.

On account of a long legal tangle between the city of Fall River and the County Commissioners, the latter being in au-

thority in the matter, several weeks elapsed before it was settled what should be done to preserve the pier, and who should do the work.

To prevent further settlement of Pier 4, the writer advised dumping crushed stone around the foundation and using a diver to push it back under the grillage as far as possible, the bottom of the river being hard, with no silt in evidence, so forming a temporary foundation.

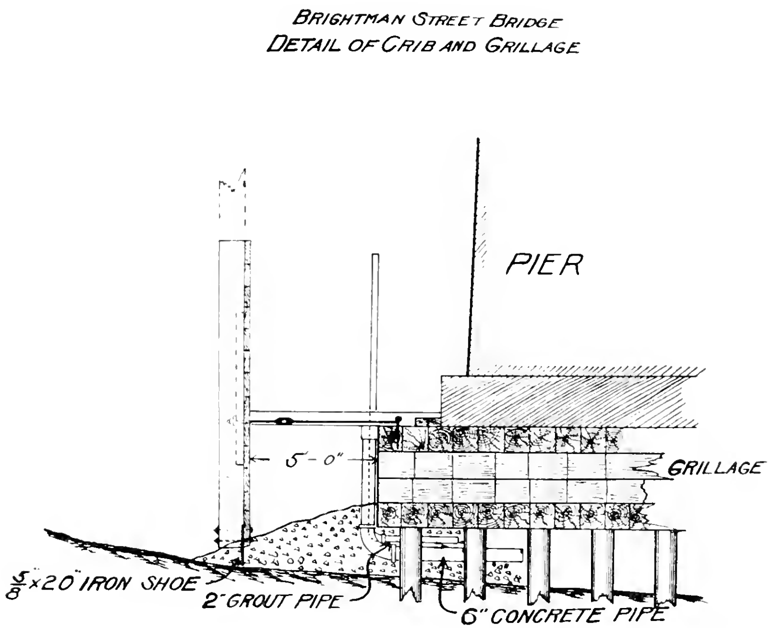

FIG. 5. SECTION OF PIER SHOWING RIP RAP AND GROUT PIPES.

The County Commissioners, by advice of the writer, "to get expert opinion on this work," retained a New York engineer — an expert on deep foundations — and the city of Fall River retained two consulting engineers, and the subject was given thorough consideration and study. The city's consulting engineers and the writer, working independently, developed plans which were almost identical, and which were adopted. The plans were as follows:

To build a bulkhead around the pier, fill outside of that with crushed stone and riprap, and between the bulkhead and grillage with strong concrete, and then through grout pipes fill all the space under the pier with strong cement grout under pressure.

First, 6 in. wrought-iron water pipes, 6 ft. long, were placed between the crippled piles under the grillage, and elbows put

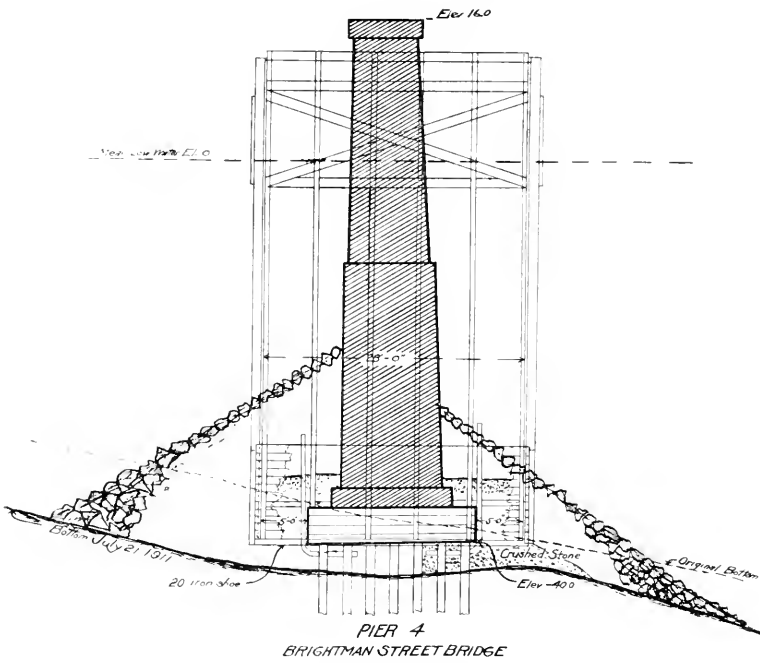

Fig. 6. Completed Repairs at Pier 4.

on them with vertical pipes about 8 ft. long fastened to them. A second set of grout pipes 2 in. in diameter were also put in, to make sure that the space between the grillage and the river bed should be made solid. The second operation was to build a form of 3-in. planks about 8 ft. high on a long timber frame of 6-in. x 12-in. hard pine, which extended 5 ft. above high water, i. e., about 50 ft. long. These frames were thoroughly X-braced

and were made in two sections on the sides, each about 30 ft. long, and the ends were made in one piece.

These forms were weighted with rails and sunk 5 ft. outside the grillages. A $\frac{3}{4}$-in. x 18-in. iron plate on the lower edge afforded a seal into the bottom of river or the crushed stone which had been deposited around the pier. The forms were held rigidly in place by struts against the grillage and with rods and turnbuckles holding the forms up to the struts.

Riprap and crushed stone were then placed outside of the form to its top, and then 1:2:3 concrete was deposited through 8-in. tremies from the top of the bridge into the space between the grillage and the forms. This concrete was made wet, to seal the bottom and the crushed stone, and was brought up *above* the top of the grillage all around the pier.

This was allowed to set up solid, and then a rich concrete, made with 1-in. pebbles, sand and cement, was forced into the 6-in. pipes, but with no great success, due probably to the fact that the concrete deposited outside the grillage under considerable pressure had been forced into all the larger cavities under the grillage. But the whole mass was then made solid by forcing grout through the 2-in. pipes, until a pressure of 100 lbs. per sq. in. would produce no flow. Lastly a great amount of riprap was deposited all around the pier, and to a greater height on the weak side.

While all this work was going on, a very interesting legal controversy was waging as to the responsibility for the failure of the bridge, which cost a million dollars and had been built only two years.

The original cost of the bridge was divided between the towns and cities in interest, Fall River paying about 55 per cent., the largest share. The legislative act authorizing the bridge provided that the cost of maintenance and repair should be divided between the city of Fall River and the towns of Somerset and Swansea and that 98 per cent of such cost should be paid by Fall River.

At the time of the failure all sorts of reports were being circulated as to the cost of repairs, — from $50 000 to $300 000, — and naturally Fall River was troubled by the prospect of

paying 98 per cent. of such an amount two years after the completion of a bridge which already had cost them over $500 000, and looked about to find some one on whom to try to put the burden of paying this repair bill. Naturally they "lit" on the contractors as the likeliest victims, and entered suit against them for the cost of repairs. All the local papers held the contractors responsible, and one of them finally went to the extent of saying they had been paid for riprap at Pier 4 and had never placed any there. As this was a direct charge of dishonesty against the contractors, the statements made being a libel on them, cognizance was taken of this article by advice of counsel, and the facts were presented to the editors with a request that the statement be withdrawn and the truth told, and this request was granted with dispatch and perfect fairness.

Briefly, the facts were these: The plan of Pier 4, the damaged pier, as furnished to the contractors by the engineer, called for piles sawed off at grade —40, filled in to their tops with gravel or broken stone, and the pier built in an open caisson resting on a 4-ft. wooden grillage of 12 in. x 12 in. timber on these piles. This construction was carried out, the pier completed, and the bridge accepted and paid for.

On August 31, the engineer wrote to the joint board advising the use of riprap at the fender, and stated further, "And again riprap for protective purposes should be placed on the river side of the Somerset abutment and adjoining *Piers 1 and 4*." On the same date he asked the contractors for a proposal to place riprap as above outlined and a proposal was made to the joint board by them, to place riprap for $3.50 per cu. yd., *to the extent required and as directed by the engineer.* This proposal was accepted on September 4, and under it some 4 500 cu. yd. of riprap were placed about the fender pier, Somerset abutment and Pier 1; but *none about Piers 2, 3, 4 and 5.*

The writer had doubts about the sufficiency of the amounts of riprap placed, and wrote the resident engineer, — "You will of course know that these waters are infested with worms which very rapidly eat up anything in the line of unprotected timber; consequently will get at the piles under that abutment (Somerset) and make trouble. Will you please think this matter over,

and I believe you will come to the conclusion that this is the only proper thing to do. As the matter stands, I think the responsibility is in a way with you, knowing the conditions fully, and consequently it is up to you to make the recommendation. To carry this thing to its logical conclusion, I think the same thing applies to the grillages, and even to the pneumatic pier, but *surely to the grillages*, that they should be protected. While Mr. Berrian limited the amount to 3 000 yd., I think this was given as an approximation, and I am certain that the joint board is willing to spend whatever is necessary to properly protect the work. We shall have the allotted amount in very soon, and must make arrangements to either shut it off or keep it going at once."

The engineer did not think it necessary to riprap the piers; consequently the work of riprapping was stopped, and the responsibility of not protecting the grillages and piles was placed on the engineer. And I am most happy to say, he, like an honorable man and a good engineer, has never shirked this responsibility, or tried to place it, even in part, upon the contractors. He said, "I didn't take any stock in your letter, that the bugs would work in 40 ft. of water. I have studied the subject carefully and can find no record of any trouble at that great depth."

The United States Department of Agriculture Forest Service Bulletin entitled "Preservation of Piling against Marine Wood Borers," states, speaking of the teredo, —

"The portion of the pile commonly attacked is between mean low water and a point 4 ft. below, though sometimes it extends downward, as far as the pressure of the water will permit. . . . They seldom work to a depth of over 30 ft., and their worst attack is in very salty, warm, clear water."

This bridge is in the Taunton Great River, several miles from the sea and a city sewer discharges into the river within 500 ft. of the bridge, so that the water is not clear, nor very salty, yet the teredo works there to a depth of 65 ft. below low water. The Fall River teredo can justly claim to have *broken the record*.

The actual cost of repair to all the piers, the work having been done without any profit by contractors, was about $60 000,

the repair work on Pier 4 costing about $25 000, and was finally paid for by the state and the bridge made a part of the state highway.

There was a very important question to engineers and contractors brought up by this failure, and the writer wishes to bring it to the attention of the members of the Society.

The plan, shown in Fig. 1, was all that was provided to show the construction of the piers, and the contract provided that " the contractor must inform the engineer as to the process he proposes to use in preparing the foundations and laying stone, also for driving piles, and must receive the approval of the engineer before beginning work."

As before stated, under this provision the engineer presented plans to build Piers 1, 4 and 5 on piles, in open caissons, and Piers 2 and 3 on pneumatic foundations, and all work was done in accordance with these plans under the direction and inspection of the engineers and to their satisfaction, and was accepted by the Commission.

The contractors did not know, nor did they inquire as to the authority of the engineer to make these plans, but took it for granted he had the authority.

The contract sketch plan, Fig. 1, indicates no method of construction, unless one infers an open cofferdam to rock in 60 ft. of water, a practical impossibility.

The contract further provided, —

" Should it be found desirable by the engineer to make alterations in the form or character of any part of the work, he may with the approval of the joint board order such alterations to be made, defining them in writing and drawings, and they shall be made accordingly."

Changes were made in Pier 1, building it on piles and not going to rock as originally provided, and this change was approved in writing by the joint board, and allowances made for the change as provided in contract. Piers 2 and 3 were to be built on solid rock, and were so built in pneumatic caissons. Piers 4 and 5 were built on piles sawed off as specified, but were built on grillages instead of directly on the piles.

These latter were considered changes, and no record was found of their approval by the joint board. As the engineer was dead and the members of the joint board probably did not know the difference between an open caisson and an open cofferdam, none of them had any recollection of the matter having been brought to their attention. So the contractors were in the position of having carried out the plans of the engineer in perfectly good faith, and because he did not get the written approval of the joint board, doubtless considering these changes a matter only of detail, they were charged with the responsibility for this lack of authority.

It would therefore seem that more than an engineer's signature on plans and his written order to do work may be necessary to protect a contractor from trouble, both financial and otherwise, even though the work is done in good faith, and to the satisfaction and acceptance of the engineer.

MEMOIR OF DECEASED MEMBER.

George Irving Leland.*

George Irving Leland was born in Milford, Mass., February 21, 1859. He was the son of George and Fanny Woods Bailey, but was adopted at the age of six years by Frederick Leland, of Upton, Mass.

He received his early education in the public schools of Upton, from which he went to the Chandler School of Engineering, connected with Dartmouth College, where he graduated in 1884.

After graduation he took a position with the Boston main drainage works, which were then in process of construction, remaining there until 1889, when he went to Lynn to take charge, under the city engineer, Mr. Gay, of the design and construction of the intercepting and outfall sewers. In 1901 he was appointed city engineer of Lynn, which position he occupied until the time of his death.

During his service as city engineer Mr. Leland had charge of many important works, including extensive additions to the water supply system of the city and the studies relating to the abolition of the grade crossings, which have resulted in the plans which are now being carried out. His chief interest, however, was in sewerage work, and practically all of the important portions of the sewerage system of Lynn were designed by him and constructed under his supervision.

Mr. Leland was much interested in the Masonic Order, in which he had received the thirty-second degree. He was also a member of the Sagamore Tribe of Red Men, of the Mystic Lodge of the United Workmen of America, of the Lynn Conclave of Heptosophs and of the Sons of the American Revolution.

He was married in October, 1890, to Miss Minnie A. Knight, who survives him.

He became a member of the Boston Society of Civil Engineers, October 16, 1889.

Mr. Leland died at Lynn, May 16, 1912, of heart disease.

* Memoir prepared by W. S. Johnson.

FREDERIC H. FAY,
President, Boston Society of Civil Engineers,
1913–1914.

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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

ENGINEERING LESSONS FROM THE OHIO FLOODS.

By John W. Alvord, M. Am. Soc. C. E.

(Presented November 19, 1913.)

The great floods of March, 1913, which devastated the states of Indiana and Ohio, will always have a direct and intense interest for engineers, and the importance of having the data carefully recorded and studied is obvious. Up to this time the main initiative which has been taken in obtaining the detailed facts has been of municipal origin. A government board is working on the general problems and it is hoped will fully develop all the further lines of inquiry which should probably be made. It is generally agreed that the main lessons to be learned from the recent great floods are as follows:

First, that there should be some authoritative and adequate public control of our streams which will prevent encroachment by bridges, buildings, populated territory, railroad embankments and dangerous levee systems, not only upon the low water channels but upon the flood plains as well.

Second, that where relief from existing encroachment is required, it should be accomplished through legislation authorizing the formation of flood protection districts, preferably covering entire watersheds, so that each problem as a whole can be given proper technical study. The cost of flood protection work should be apportioned in some fair relation to the benefits and value of the affected interests.

Note. — Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before May 15, 1914, for publication in a subsequent number of the Journal.]

Third, that, while Indiana and Ohio cities have recently received a severe object lesson, there are many other cities and towns in this country which have so encroached upon the adjacent river beds as to be already in peril. They should not be permitted to await a physical demonstration of their danger, but should be aroused to the problem of protection from destructive floods.

Fourth, the studies at Columbus and Dayton, as far as made, indicate that radically different methods of treatment are often required for communities apparently similarly situated.

No generalization as to the relative merits of reservoir versus channel improvement methods will take the place of thorough investigation and study of the local situation and sound deduction from the facts thus disclosed.

The Storm of March, 1913.

With these general conclusions in mind, I desire to invite your attention to some of the main features of two flood districts in Ohio which it has been my opportunity to study. These are the Scioto at Columbus, necessarily including Delaware and Chillicothe, and the Miami River and its branches at Dayton, covering Troy, Piqua and Miamisburg on the Miami watershed. The flood story in all these places is essentially the same. Insidious encroachment followed out for years, not only upon the low water channel, but upon the flood water plain, had so reduced the channel capacity created by nature that only about one quarter to one third of the flood water could be accommodated in the regular channels. The remainder of the flood rose until it overtopped the levees and swept through populous areas with destructive velocities which demolished houses and caused death and widespread suffering.

The great storm which created this condition is worthy of special notice. It had been preceded in the same month by storms of considerable strength which passed over the same area, and on the morning of March 20 a storm developed over the Rocky Mountain and Great Plains states which moved rapidly eastward and, joining during the afternoon of March 24, a second storm, which had developed over the Southwestern

states, covered an elongated area enveloping the Ohio Valley watershed continuously for a period of sixty hours or more. It was accompanied by excessive rains and the most widespread and devastating floods of modern times. The combination of these storms caused them to pass in a southeasterly direction over central Ohio. The greatest intensity of rainfall centered directly on the divide which separates the waters flowing north into Lake Erie from those flowing south into the Ohio River, then moved southeasterly down those streams, undoubtedly accentuating the flood waves.

In the territory above Columbus and Dayton the greatest precipitations were observed at Bellefontaine, Marion and Richmond, Ind., where about $11\frac{1}{2}$ ins. were recorded for the four days, and on Tuesday, March 25, from three to four inches fell all along the upper portion of the Scioto and Miami watersheds, coming on top of the several inches which had fallen on the two previous days. Some three inches fell on the Scioto River watershed above Columbus even after the crest of the flood had passed the city, which accounts in part for the slow decline. No other storm as great in area and intensity as this has been recorded in this country, outside of the Pacific slope, but it must be obvious to any one who studies the flood water plains of these and other rivers that great storms of this kind have occurred and flood waves have been produced which were fully as great, if not greater, than those recorded in Ohio and Indiana in March, 1913. The normal flood plains of the rivers were occupied fully as they have been time and again during the recent geological past. When we remember the comparatively limited time over which records of great storms have extended in this country, we must realize that one of the urgent lessons which the engineer has to learn is not to place too great reliance upon them.

It is interesting to note the accumulated rainfall at Columbus and Marion, hour by hour, during the four days in which it took place. The rise is fairly constant in both cases, although on the final day the excessive amount of over 11 ins. at Marion appears in comparison with the 7 ins. which accumulated at Columbus.

It is no wonder that the astonished inhabitants of Dayton and Columbus could not understand where such a vast quantity of water came from. Rumors of reservoirs having broken circulated in both cities, and the presence of reservoirs on their upper watersheds gave foundation to them. None of the younger generation had seen floods cause such serious damage, and even the older people had not seen floods of such magnitude. The Ohio State Board of Health is authority for the statement that in Ohio alone 430 lives were lost, 104 municipalities inundated, 20 000 homes completely destroyed, and 35 500 other homes rendered uninhabitable.

Someone has estimated that the amount of water which fell in Ohio and Indiana during this storm would raise the level of Lake Erie, with an area of 10 000 sq. miles, approximately 4 ft.

The Flood at Columbus.

It is of interest to contrast the local situations in Dayton and Columbus and, for this reason, it is desirable to describe more particularly the topographical features which contributed to the especial disaster at each of these places.

At Columbus, the Olentangy and Scioto rivers, emerging from parallel rock gorges in which they have flowed for twenty-five miles or more, unite just above the West Side of the city upon a broad flood plain nearly a mile in width. The slopes of both rivers above this point are much steeper than below, so that water is launched upon the broader and flatter flood plain with greater rapidity than it can be properly carried away. The Scioto River crosses the flood plain just north of the populated part of the West Side, uniting with the Olentangy near the east side of the flood plain, passing close to the rising ground on the east side near the central portion of the city, then around what is locally called the "Bend," thence winding through the flood plain from side to side.

Levees from ten to fifteen feet high were raised along the northerly part of the West Side after the flood of 1898 to protect it. Thus confined, and reduced in width by encroachments,

the river channel around the Bend had a capacity less than one half of that needed for a flood such as occurred in March, 1913.

The natural result of this condition was the ponding of the waters above the dikes until they were overtopped and washed completely away in many places. The flood waters swept through the numerous breaks with great swiftness and demolished buildings, tore up pavements and caused great general destruction and loss of life.

It should be remarked that the buildings on the west bank of the river around the Bend are built upon made ground which encroaches upon the river channel proper, and that there are also numerous bridges, many of which were destroyed. The capacity of the Scioto around this Bend was hardly more than 50 000 sec.-ft. at high flood stage, but after the scouring of its bottom with many depressions 25 ft. or more in depth, and with increased slope, it perhaps carried a maximum of about 70 000 sec.-ft., while the flood flow at the crest of the flood is estimated to have been 140 000 sec.-ft.

The Flood at Dayton.

In Dayton the situation was likewise especially endangered by the fact that four rivers converge just above the center of the city: the Mad River, with 680 sq. miles; the Miami, with 1 160 sq. miles; the Stillwater, with 650 sq. miles; and Wolf Creek, with 50 or 60 sq. miles; all having a combined catchment area of about 2 550 sq. miles. The channel through the central part of Dayton, being only about 500 or 600 ft. in width, could barely carry 85 000 to 90 000 sec.-ft., while the estimates of the recent flood maximum are from 240 000 to 260 000 sec.-ft.

Of the six bridges spanning the main stream at Dayton, four reinforced concrete arch bridges held like adamant, while the steel bridge at Fifth Street and the railroad girder bridge were carried away. A hydraulic engineer ventured out upon this latter bridge, during the highest stage, and measured a difference of five feet in the levels on the upstream and downstream side. This was in part due to the tremendous amount of drift which accumulated there.

The first water invaded Main Street in Dayton at 9 A.M., March 25; one hour later it was 3 ft. deep at the same place and by one o'clock it was at least 10 ft. deep. The work of cleaning the city after the flood went down was of great magnitude. Estimates of the amount of silt deposited over the town vary from 4 to 6 ins. In some places where excessive deposits occurred they were removed with steam shovels. People were obliged to push the ruined contents of their lower floors out into the streets, and the city was busy for several months after the flood carting the accumulations away.

Damage at Columbus.

The value of the property in the flooded district of Columbus is estimated to have been fifty million dollars, and the direct loss caused by the flood, not including indirect damages, is estimated at seven and a half million dollars.

Some idea of the devastation can be had from the following summarized statement taken from the Columbus Report:

The entire city was without water for twenty hours.

The West Side was without water for about one week.

All the public schools were closed for three days and the nine public schools on the West Side were closed for about five weeks.

The levees of the West Side were not entirely repaired for over four months and the railroads were unable to operate on their own tracks for periods ranging up to about one month.

Street car service throughout the entire city was abandoned for two days and badly crippled for about one week, and no street cars were operated on the West Side for ten days after the flood. Communication across the river by car was not reëstablished for a month.

Cleaning the streets of débris and removing flood deposits consumed the best part of two months, and the repaving of damaged streets was still going on three months after the flood.

A very large portion of the houses on the West Side were so damaged that at least a month elapsed before they could be restored to habitable condition.

Reservoir Panics.

With the perils and distress of the flood, there came to nearly all the inhabitants of both Dayton and Columbus a panic produced by the rumors that important reservoir dams

had given way. After the strain, which nearly everybody involved had been under, it is not strange that even strong-minded people should have been ready victims of such a rumor. No one could understand where such a vast quantity of water could have come from. In Dayton, the water was at least 8 ft. higher than any one could remember it to have been before, and the immediate thought was that the reservoir dams upon the upper watersheds had given way and added to the already dangerous floods. An untold amount of mental suffering was produced for some hours in both Dayton and Columbus by this fear. It is a question whether the terror inspired by these panics will permit those populations to calmly contemplate the construction of great reservoirs on the watersheds above their cities for the purpose of protection. Where they are plainly the most economical and efficient way of controlling floods, their dams must be very ample in their proportions and stable in their design if they are to receive the confidence and approval of the people.

Another engineering lesson which can be profitably drawn from these flood scenes is the necessity of providing free waterway under bridges for débris. All great floods are drift-laden, and houses, barns, fences, haystacks and wreckage of all kinds quickly lodge where an insufficient waterway is provided, still further reducing the area.

Details of Devastation.

One of the factors which aggravated the flood conditions and contributed to the loss of life in Columbus was the extensive track elevation which had been recently completed there. The elevated tracks were on embankments of considerable height and stability which the flood overtopped in many cases, but usually the water found egress through the subways, where currents were created which must have reached velocities of from 18 to 25 ft. per sec. Such velocities, operating for hours, were particularly destructive to the municipal improvements and the buildings in their vicinities. Great holes 15 to 20 ft. in depth were washed out at such places in the paved streets; houses were swept away and vast masses of loose rock of large size

were carried great distances and spread to a depth of 3 or 4 ft., sometimes over areas of several acres.

The flood of 1898 in Columbus, while of considerable magnitude, did not have anywhere near the devastating effect of the flood of March, 1913, due largely to the fact that in former times the levees above the town were comparatively low, and that no track elevation existed.

After the flood, most of the people of the flooded West Side district were compelled to live for many weeks in their second stories. Many of the houses, especially those of brick, were rendered uninhabitable for months by the saturation of their walls.

Horses were generally drowned when caught within the flooded districts. They seemed to have no sense which would guide them to the higher grounds, although having strength enough to swim for hours in strong currents before becoming exhausted. But the submerged automobiles rose to the occasion. A little cleaning and they were ready to do splendid service in relieving distress, conveying food supplies and doing work that could never have been done otherwise to rehabilitate the city.

Railroad Destruction.

The damage to the railroads was very great throughout the entire flooded area and traffic was suspended for a week or more. In an instructive booklet issued by the Pennsylvania Railroad a diagram is given showing the interrupted and abandoned tracks of their lines west of Pittsburgh, and this gives a good idea of the area and magnitude of the flood disturbance.

As a typical instance of railroad destruction, attention may be called to the Big Four Railroad's new cut-off lines below Dayton. This great work had just been completed at an expense of some millions of dollars when it was put out of commission by the flood of March, 1913. Below Miamisburg, where a high embankment crosses the flood plain of the Miami River, the swift currents created were instructively interesting. The largest part of the flood passed under a new girder bridge over the Miami River, but a considerable flow, perhaps 25 000 to 50 000 sec.-ft., found its way under a heavy double track bridge

over the Miami and Erie Canal. Here the velocities must have been very great, probably at times reaching 20 to 25 ft. per sec., as indicated by the upstream and downstream high water marks. A great pit was excavated below the bridge and large bowlders and thousands of tons of stone from it were distributed over a wide field below with interesting regularity, showing a gradation which would do credit to the best sorting screens ever designed.

These phenomena have raised the question as to whether some rough rule could not be formulated which, from the weight of the stone moved, would give the velocities created in the water, but amid the necessity for more important studies, this interesting side phase of the subject has not received attention.

There was deposited below the Big Four bridge a pile of assorted gravel many hundred feet long and from 8 to 12 ft. high, which was dropped at this place by the retardation of excessive velocities. It is interesting also to note the scour which took place around the water-works station at Richmond, Ind., and the ability of sod, as compared with large bowlders, to resist erosion.

Rock Erosion at Columbus Dam.

Perhaps no other effects of this great flood show the intensity of the forces at work as do those resulting from the overflow at the Columbus storage dam. It is roughly estimated that the flood in its passage over this dam and through Columbus would, theoretically, have created over a million horse-power, the larger part of which was dissipated in internal work of the rolling water. At certain points, however, where this power was not so dissipated, its effects were of a most marked character. Some idea of the external work which was performed by the water after passing over the crest of the dam can be had by examining the channel just below as it appeared when the river was again low. Great rocks, some of over three tons weight, were quarried from the bottom of the river, carried downstream some hundred feet, and piled up in a dike. (Fig. 1.) The rock at this point is laminated limestone, lying in nearly horizontal strata.

A survey which has been made indicates that in places at least 10 ft. of solid ledge rock was removed from its bed. It does not appear that the stability of the dam is much affected so far, as it is unusually strong both in weight and profile for the heads which it has to carry, but to any engineer who is constructing dams, and who has had to do with the enormous

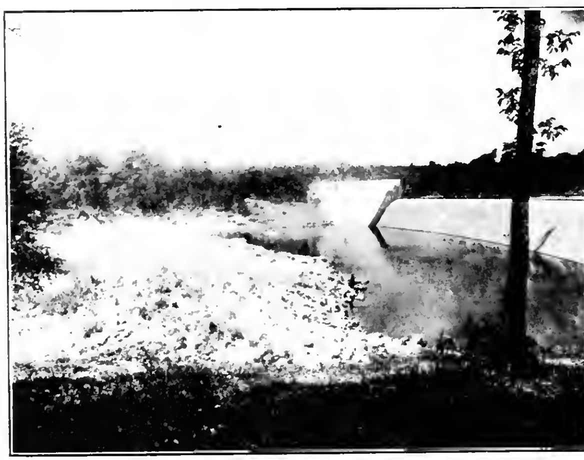

FIG. 1. EROSION AT COLUMBUS STORAGE DAM.

forces created by large quantities of water rolling over crests, these facts are certainly significant and instructive, and may be profitably recalled when designing similar structures.

FLOOD MEASUREMENTS.

In taking up the problem of flood protection, the first study necessarily was to determine, as nearly as possible, the amount of the flood of March, 1913. At Dayton, this work is in charge of the Morgan Engineering Company, and it has been difficult. The best opportunities for measurement have been found only in the difference of head which the flood marks show above and below certain bridge openings, through which the entire flood, or nearly the entire flood, passed.

The Big Four bridge below Miamisburg, which was badly wrecked by the flood, is one of the places in which this determina-

tion has been attempted. The chief difficulty lies in the fact that we have no means of knowing, with any degree of satisfaction, the varying cross-section below the low water line, which was materially increased during the flood by the enormous scour. This scour wrecked the foundations of the piers and created deep elongated pits in the bottom of the river, leaving mounds in some cases upon which the bridge piers stood. These and other embarrassments make it difficult to determine, within close limits, what the flood flow in the Miami may have been. At Columbus, the passage of the entire Scioto flood over the crest of the storage dam, with the hourly records of its height, afforded data of unusual interest, and well defined the quantities of flood flow.

The Columbus dam is 500 ft. long on the crest, about 30 ft. high, and is founded upon rock. Its profile is very ample, as it was the intention at some time in the future to raise its crest to a considerably greater height. The original design of the spillway provided for 6 ins. of run-off in twenty-four hours from the watershed above. Such a run-off would have caused the water to flow over its crest to a depth of something like 22 ft. Actually the flood of March, 1913, reached a head of 12.8 ft. on the crest, as measured by a gage on the upstream side.

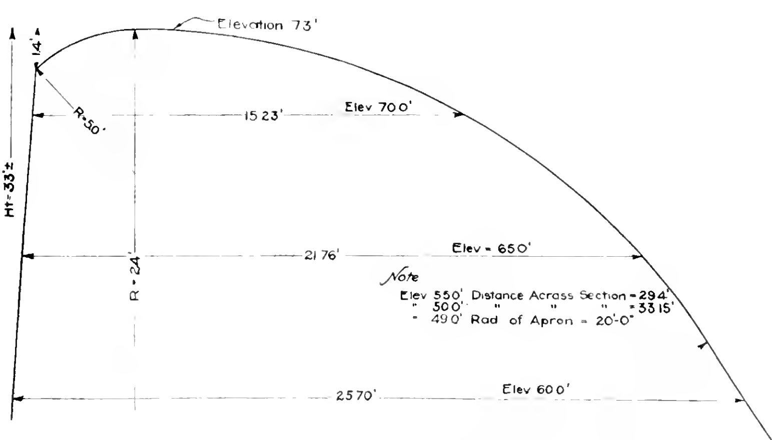

FIG. 2. FORM OF CREST, COLUMBUS STORAGE DAM.

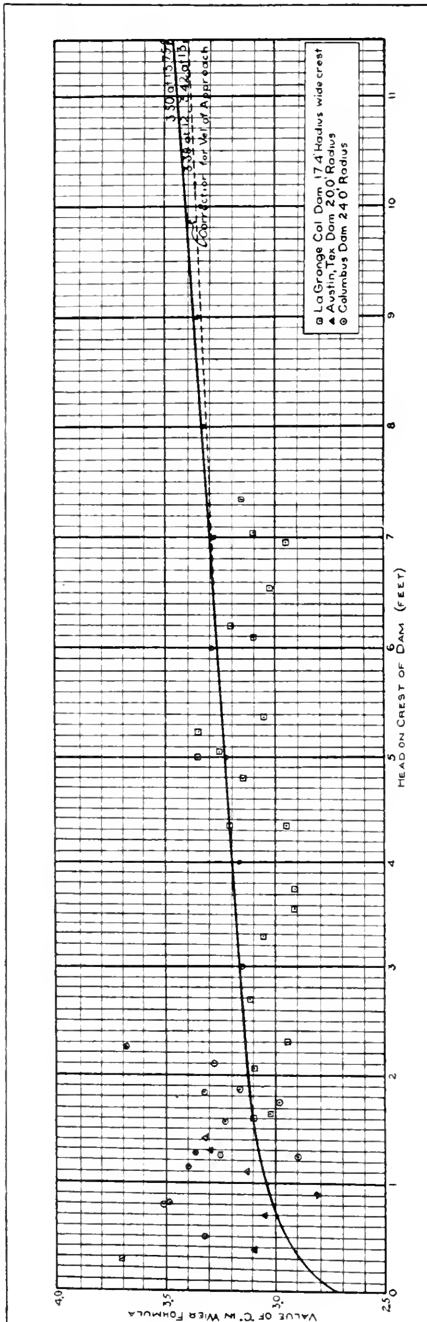

Fig. 3. Curve showing Value of "C" in Francis Formula.

It became a matter of importance and interest to study carefully all of the available data showing the value of the coefficient "C" in the Francis formula, for crests of this type and for this head, the profile of the Columbus dam being as shown in Fig. 2. Besides the Columbus dam, there was available the profiles and accurate data of the La Grange dam (which is somewhat similar), the Austin dam and certain dams which were used in the experiments by the United States Board of Engineers on Deep Waterways at Cornell University. It should be noted that the greatest head for which we have definite information occurred on the La Grange dam, upon which flows of over 7 ft. in depth have been measured.

It is not possible to review here the methods of reasoning which were adopted in determining this question. Those who are especially interested will find them fully stated in the report on the Columbus flood protection. The general conclusion, from an analysis of all the available information, was that the coefficient was not increased to any marked degree by reason of the special type of crest, and that heads of 12½ ft. on the Columbus dam would not produce a coefficient of more than 3.5 for the Francis formula. The curve which was finally concluded to be warranted, and which has a lower value than that assumed by a number of engineers just after the flood, is shown in Fig. 3.

One very convincing argument in favor of the belief that this determination of *C* was conservative lies in the fact that applying greater coefficients than those indicated by the curve would have resulted in demonstrating that more water passed over the Columbus dam during the flood period than fell as rain on the watershed above. The average rainfall on the watershed above the Columbus dam was 9.34 ins., while the run-off, compiled by the above curve of coefficients, was 8.63 ins., giving a run-off of 93 per cent. of the rainfall. This is a high rate of run-off, but to decrease it would be to decrease the value of the coefficient *C* materially below what it is believed a conservative investigator would be willing to assume.

At Columbus, it was also necessary to measure the flow of the Olentangy River. The best opportunity for this was at Delaware, about 25 miles above Columbus, where at a bridge

opening through which the entire flood passed the water marks above and below were distinctly recorded. The bottom of the river, being rock, there was no considerable change of cross-section, except that due to the destruction of the center pier of the bridge and some erosion of the roadbed of the Pennsylvania Railroad, which passes under the western span. The conclusions as to the flow of the Olentangy are not based upon so secure data as were available for the flow of the Scioto, but it is evident that the flow of the Olentangy was considerably greater than that of the Scioto per square mile of drainage area, as might be expected from its smaller watershed, the final conclusion being that the two rivers combined gave 89 sec.-ft. per square mile of drainage area. The Upper Scioto from the measurement at the storage dam yielded 77 sec.-ft., while the Olentangy, measured at Delaware, yielded 115 sec.-ft. per square mile of drainage area.

Erosive Currents.

As has been said, the marked loss of life and the most serious destruction in Columbus occurred in the vicinity of the levee breaks and the subways where the impounded water found vent. The destruction under the tracks of the Toledo & Ohio Central Railroad, located on the levee at Sandusky St., was almost complete. The great 36-in. main of the Columbus water works, which feeds the West Side, was here destroyed. This put the water supply of the entire city out of commission for almost an entire day until the water subsided far enough so that a valve could be reached which would stop the loss through this break.

The high velocities that were created at the subways, where heads as high as 10 and 12 ft. were noted between the upstream and downstream water lines, did great damage both above and especially below them. Almost all the houses in their immediate neighborhood were destroyed and if not swept completely away they were overturned, piled up and practically ruined

The destruction in the Toledo & Ohio Central Railroad yards at Columbus, by breaks in the levee just north of it, was very great. Most of the damage was caused by the height of

levee which, when overtopped and broken, caused high velocities in the vicinity.

In Columbus, the Baltimore & Ohio Railroad track elevation formed an almost complete impounding reservoir, through which there were only four subway outlets. The one at Sullivant Ave., caused great destruction, a pit being excavated to a depth of 24 ft. below the street level. (Fig. 4.) The abutments of this subway were built of 2 ft. dimension stone, and they held together well. The entire abutments, however, were undermined, a large portion of one being carried clear across Sullivant Ave.

Fig. 4. Sullivant Ave. Subway under Railroad after the Flood.

Many people were drowned at this point because of the rapid current. Houses from above the subways were sucked into it and their inhabitants drawn down into the rushing water, without hope of escape. A field of bowlders many acres in extent covered the district below this subway to a depth of 3 or 4 ft., and nearly a hundred houses were swept away.

The erosive effects on different types of surfaces were noticed by Prof. C. E. Sherman of the Ohio State University immediately after the flood. Sod appeared to withstand erosion

much better than macadam, but it was observed that when the sod did begin to give way through the erosion, it was destroyed in long furrows, giving the appearance of plowed ground. The resisting power of sod against erosion has been well-known, but the effects observed in Columbus will renew confidence in sodded slopes.

Projects for Relief.

In considering projects for relief, it was, of course, important to decide upon the factors of safety which should be introduced. From a review of all the large storms in this country, there can be no doubt that the storm which covered the Ohio Valley in March, 1913, was one of the very great storms; nevertheless, it is easy to see that all of the factors producing large storms were not present. If the heaviest precipitation had occurred entirely within the Ohio Basin, or within any one of the different tributaries, or if the precipitation had occurred with a great depth of snow on frozen ground, the run-off would have been greater and more sudden than was actually the case.

On one part of the Scioto watershed there was in operation a large natural restraining reservoir, which caused the water from the upper watershed to be detained, and which prevented additions to the crest of the flood, and further, three inches of the total rainfall occurred after the crest of the flood had passed Columbus. Under these circumstances, we must admit that the flood of March, 1913, might be materially exceeded in the future. It was a difficult question to decide on what scale of protection projects for relief should be based. It was finally decided to adopt at Columbus at least two scales of protection, in order that all might fully understand the relative costs involved.

Factors of Safety.

The results can be best shown upon the well-known chart made by Mr. Emil Kuichling for the Deep Waterways Commission some ten or twelve years ago. (Fig. 5.) While all of the recent great storms are not upon this chart, the more important ones here considered are noticed, so that we may vis-

ualize them as a basis for reasoning, in the light of the great storm which just occurred. It must be remembered that in works for relief we have not only to deal with great floods, but great floods which may be accompanied by ice gorges, accidents to bridges, accumulations of débris and other difficulties which make it imperative to extend our factors of safety much more than would be necessary if they were predicated on flood heights alone. For this reason, at Columbus, bridge clearance was generally made 6 ft. above the adopted high water mark and levees were carried ten to twelve feet above this mark everywhere except at a few of the more important bridge crossings, where they were 6 ft. above. This, with some emergency work, would give a factor of safety of about one half more than the actual flood upon which the relative projects were predicated; thus works for protection against a flood of 150 000 sec.-ft.

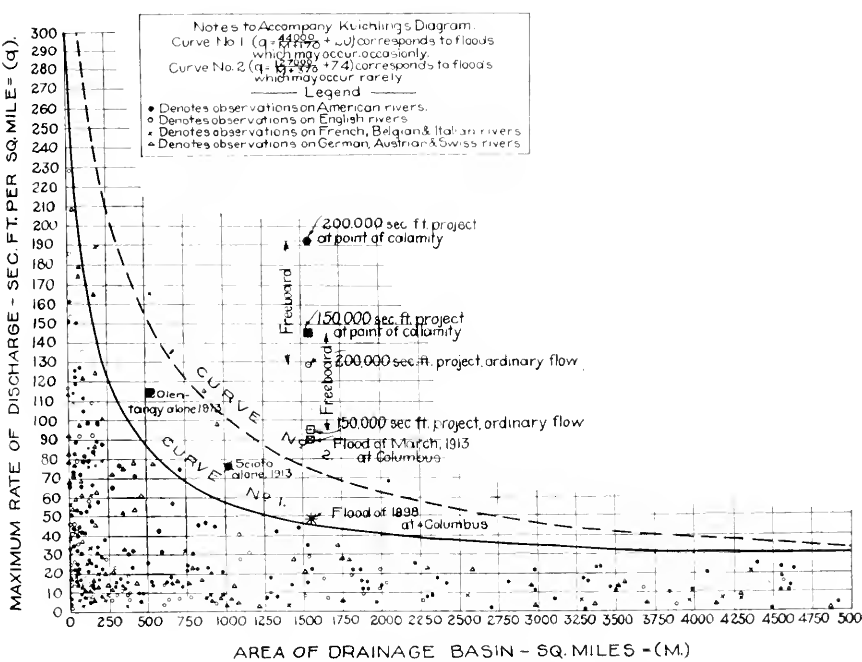

FIG. 5. RATE OF MAXIMUM FLOOD DISCHARGE.

would actually have a capacity of nearly 225 000 sec.-ft. before a great calamity would occur, and likewise works for a flood of 200 000 sec.-ft. would have really about 300 000 sec.-ft. capacity.

The very great cost of works for protection, in proportion to the value of the property to be protected in Columbus, seemed to point to the necessity of adopting the lower class of projects as being reasonably complete and stable. It may be suggested that an economic comparison, based on the value of the property to be protected, would be illuminating. This might be useful had we only to consider property and financial value, but in problems like those at Columbus and Dayton, where thousands of people are living at lower levels than the necessary flood heights, it is obvious that reasoning, based on financial considerations alone, will not suffice. Human life and suffering cannot easily be capitalized.

Reservoir Projects.

Very early in the investigation it was found that large reservoir storage was possible both above Columbus and Dayton. Above Columbus the watershed of the Olentangy and Scioto rivers is a gently rolling one in its upper courses. Some parts of the upper Scioto are indeed quite level and formerly comprised a large marsh. For about 25 miles above Columbus, however, both rivers flow parallel through a rock gorge from 500 to 1 500 ft. in width and from 60 to 100 ft. in depth. There are few tributaries entering the rivers in this reach, and a number of good sites for high dams can be found. Those which were the most available were located and it was estimated that about two inches of rainfall on the watersheds above them could be stored in reservoirs whose cost would not be excessive. Other reservoir sites than these were observed to be practicable, but with greatly increased cost due to the better value of the agricultural lands utilized. It will be observed that the March, 1913, rainfall of 9.34 ins. would be nearly five times the available economical storage. The small proportional storage led to some embarrassments. Speaking generally, however, it was fortunate that such good sites were found so near to the points

to be selected, and upon lands which were either not farmed or were not of high value.

Delaware, as well as Columbus, would be materially benefited by a storage dam immediately above it, and it was clear from the studies made that the more numerous the communities to be protected, the more advantageous general storage becomes.

It is interesting, as bearing on the general proposition of reservoirs for flood relief, to note how the different conditions in Columbus and Dayton pointed toward different solutions of the proposition. For Columbus, projects with a fraction of the flood stored in reservoirs, combined with channel improvement, were found to be not materially cheaper than a channel-improved project alone, but in Dayton the Morgan Engineering Company has found that supplementary channel projects are so expensive, and available reservoir sites so much nearer the full flood capacity required, that everything now seems to point to reservoirs as the proper solution there, while channel improvement is the proper solution for Columbus, considered by itself.

In the Dayton watershed, the reservoirs approach very much nearer in capacity to the run-off to be provided for than is the case in the Columbus watershed. There is one reservoir proposed on the Stillwater River above Dayton which will hold over 12 ins. of rainfall from the watershed above it, and another, on the Mad River, has a capacity for 6 ins. of rainfall on the watershed above it, and there are three others with a goodly capacity for a proportion of the rainfalls which they might receive. This reduces some of the difficulties of reservoir projects, because where reservoirs have only a fraction of the capacity of the probable rainfall they must be constructed so that large quantities can pass over their spillways, and thereby secondary flood waves may be created which are often but little less in height than the original flood wave would be.

It is hard to realize the magnitude of these reservoirs for full flow. In the March, 1913, flood the Dayton reservoirs would hold 1 500 000 acre-ft., and the Columbus reservoirs 750 000 acre-ft. To safely store this vast amount of water in close proximity to the city is indeed a problem. It is theoretically possible at Dayton to take care of almost all the rainfall

which occurred March last, leaving about 50 000 sec.-ft. to flow through the present city channel, which would not tax its capacity.

Another fact which works in favor of the reservoir solution at Dayton is that the dams there can be largely constructed of earth, while at Columbus, owing to contracted sites, and the necessity for large spillways, the dams must of necessity be of concrete.

Detaining Type of Dams.

As a typical example, let us take the dam on the Scioto River proposed for the protection of Columbus, known as the "Dublin dam." All of the proposed Columbus dams are to be of the "detaining type"; that is to say, constructed with large openings in their bases which will permit light floods to pass freely through them without detention while larger floods will be partially detained, and great floods more largely detained. It is obvious that the greater portion of the lands above this type of dam would not be flooded except when a quite large flood occurred, so that, with reasonable precautions, they could usually be cultivated. It is not, therefore, necessary to devote such lands entirely to reservoir purposes, but it is evidently necessary that the land should be owned and controlled for the purpose for which it is designed. "*Calamity reservoirs*," as we may properly call them, should not be filled for any other purpose than to detain great and destructive floods, unless a certain definitely defined proportion of them be conserved for other purposes and excluded from consideration for flood protection purposes. Whether this is safe and certain under our American municipal conditions is an open question.

An interesting set of curves has been worked out for the Columbus conditions, which show the theoretical effect of different amounts of storage in flood protection; first, where under control by gate regulation; and second, by automatic detention. Theoretically, it seems possible, with any given amount of storage fractionally less than the full flow, to reduce the crest of flood waves by the amount of such fractional storage, but to accomplish this practically, the operator would have to have

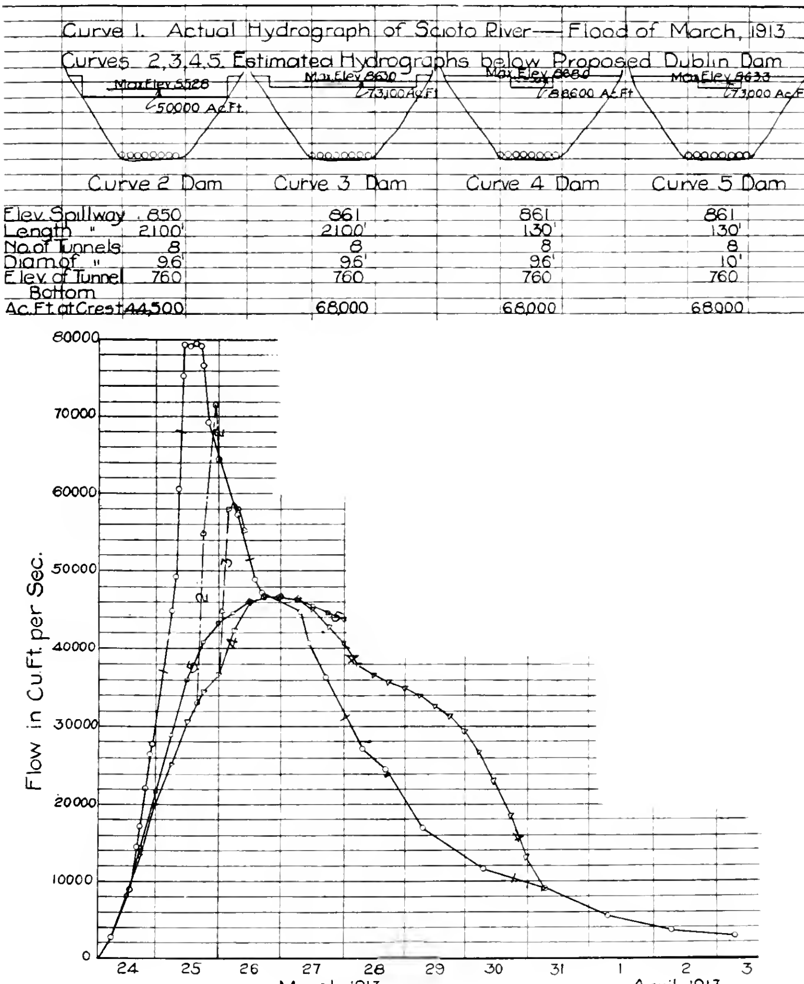

FIG. 6. HYDROGRAPHS OF SCIOTO RIVER BELOW PROPOSED DUBLIN DAM SHOWING EFFECT OF VARIOUS DAMS AND SPILLWAYS IN REDUCING FLOOD OF MARCH, 1913.

a foreknowledge of just where on the rising flood to begin to store.

With reservoirs practically effective and which automatically operate, that is to say, of the detaining type, designs must be made for a certain type of flood graph, and for other types of flood, graphs may not be so efficient. At Columbus, studies were made upon the actual flood input and output of such reservoirs as were possible on the Columbus watershed. Nearly all of the reservoirs, both at Columbus and at Dayton, would store quite as much water in the upper ten or fifteen feet as in the lower sixty or seventy feet. It becomes important in so-called fractional storage, under these conditions, to know what size and height of spillway and size of sluiceway is best, in order to get the best results in effectively cutting off the crest of any theoretical flood wave. Under the particular conditions of the Dublin dam, for instance, it developed that a deep and short spillway was most effective. In the diagram (Fig. 6), the different curves show important differences in efficiency due to the varying height and length of spillway and amount of opening.

A further diagram was constructed to show the final detention efficiencies obtained by the Dublin and Delaware dams above Columbus, which together were finally counted upon to detain safely 50 000 sec.-ft. of flood flow. Economically, it seemed undesirable to introduce any more storage than this for the protection of Columbus alone.

The adoption of the detaining type of reservoirs at Columbus was largely due to the desire to avoid reliance on human vigilance, thus all operated types of flood relief were excluded from consideration as a matter of principle. In works which are only to be used once in twenty-five or fifty years, it does not seem prudent to rely upon human vigilance. Much cost might be saved if certain types of control gates and emergency dams could be introduced in works in the city and for channel improvement, but all of these were discarded, under the circumstances, as being unsafe and improper of application to a problem of this kind.

It is also to be questioned if great outlet gates are practi-

cable in emergency dams, or so-called "calamity reservoirs." Such gates must necessarily be very large, exceeding in size most of those now used, and operated by power, as they must be, and at infrequent intervals, their introduction is questionable.

The Recommended Project at Columbus.

The recommended project at Dayton has not yet been finally worked out. At Columbus, that recommended might be described as a "channel straightening project." The West Side, consisting of a long, narrow, populated area crossing the valley like a dam, is to be crossed by a proposed new channel about 6 000 ft. long, 900 ft. wide at the top, and 600 ft. wide at the bottom. Above and below this new channel the river is to be confined by levees, converging to the channel on the upstream, and diverging from it on the downstream side, so that the flood may gather itself together for its flow through the channel, then spread itself out again upon the flood plain below the city. A mean velocity of 8 ft. per sec. was considered the highest desirable within the artificial channel, and 10 ft. mean velocity was considered the limit for bridge openings.

The cost of the recommended project was over $11 300 000, of which about $8 500 000 would be represented by the city's outlay and the balance by the railroads and other interests.

The expensive part of such a project is comparatively short at Columbus, which fact accounts for the favorable comparison of channel-straightening projects as against reservoir projects. In Dayton the reverse is the case. Any channel project there must be several miles in length through well-populated areas. In Columbus, the character of the houses in the district where the improvements would be made was such that it was found to be more economical to provide width of channel than great depth. Three fine reinforced concrete arch bridges are proposed to take the place of five or six old steel bridges existing on the Bend. Two railroad bridges may be dispensed with under the new plan, and only two new railroad bridges will have to be provided. Superior access is given to the city from the West Side, and the old abandoned river channel,

amounting to about 65 acres, might be filled, if desired. About seven hundred and fifty houses would have to be taken down or removed, most of them being wooden buildings of the cheaper grade, although one or two good churches and some good store buildings are included.

The city of Columbus has already voted upon a proposition to issue eight and a half million dollars' worth of bonds to initiate this improvement, and while considerably over a majority were in favor of the proposition, the law in Ohio requires a two-thirds majority, which was not attained. People from the flooded district voted for the proposition almost to a man, but other members of the community residing on higher ground did not appear to relish the proposition to pay for the work with a blanket bond issue, the proceeds of which would be very largely used in one section and that the least valuable in the city; consequently enough votes were cast against the measure to defeat it.

It is probable that during the coming winter measures will be introduced in the Ohio legislature looking toward the formation of flood relief districts, by means of which Dayton can combine with its adjacent cities and apportion the benefits more properly and justly than would be otherwise the case. Such laws would permit Columbus to consider more carefully the question of reservoirs in combination with Delaware and other smaller cities which might be benefited thereby. In any event, it would appear that a law which would provide for the special assessment of at least a portion of the benefits ought to be passed so that a more equitable adjustment of the costs upon the property benefited within the city could be made.

DISCUSSION.

By Messrs. F. A. Barbour, Desmond FitzGerald and Francis C. Tucker.

F. A. Barbour. — The Society is to be congratulated on the presentation of this comprehensive discussion of the flood of last March by Mr. Alvord.

The writer had some experience in the investigation of possible methods of flood control at Tiffin, Ohio. This city, with a population of 12 000 people and a total valuation of $12 000 000, sustained tangible losses approximating $1 000 000. Nineteen lives were lost, six bridges were swept away, river walls were practically destroyed, 46 buildings were carried off and 418 other buildings more or less damaged.

As a result of this experience, an investigation was undertaken by the city to determine the best method of preventing a repetition of the calamity. Without entering into any detailed discussion of the problem, or of the improvement proposed, it is believed that some phases of this investigation may be of sufficient general interest to merit brief consideration. In the first place, the engineer undertaking such an investigation for so small a city is at once forced to recognize that the important problem is to determine what can be done for an expenditure within the financial capacity of the community rather than what should be done to provide against such a flood as the records of the local or adjacent streams indicate may occur.

The Sandusky River at Tiffin has a watershed of 1 030 sq. miles, or about the same as that of the Scioto at Columbus, but it is obvious, other things being equal, that the smaller city cannot undertake works to provide for the same flood discharge as the larger city; it must either move above the flood plain, or assume a risk until its growth and the increased value of the exposed property justifies the expenditure necessary for more adequate protection, or until the state or federal governments coöperate in flood control.

The maximum discharge of the Sandusky River at Tiffin, as determined from the areas of the waterway and the slopes recorded by levels taken of the well-defined maximum elevation of the flood in several stretches of the river, using Kutter's mean velocity formula with $n = .030$, was at the rate of 64 sec.-ft. per square mile. The rainfall, so far as can be told from the comparatively few stations reporting, was practically equal to that on the Scioto. As this run-off resulted from rainfall at a time when no snow was on the ground, it is obvious that it may be exceeded in the future, — a fact which was duly emphasized in the report submitted. The statement of the possibility of a greater future flood was, however, of more academic than practical interest to the local authorities, who set a certain expenditure as the maximum which could be considered, and which, incidentally, it may be noted, will increase the tax rate about $2.00 per $1 000 of total valuation, although only a small part of the city will receive any tangible betterment. The development of some rational method of assessment which will apportion the tax in the ratio of the benefits received, and which might possibly include contributions from the state and national governments, would materially aid in making it possible for individual communities to undertake adequate flood control.

The immediate problem at Tiffin was, therefore, to determine the present improvement which would provide for the greatest discharge within the money available, but which should form a permanent part of an ultimate scheme which could be progressively developed in the future to the condition necessary to care for the maximum possible flood.

It was concluded from the studies at Tiffin that the available money could best be expended in widening the channel through the most congested section, confining the work to that portion of the river where property values are highest, in order that the new river lines might be established before any reconstruction of the damaged buildings could be undertaken. River walls are to be constructed for a distance of 2 500 ft., and the areas between the river and the next adjacent street parallel with the stream are to be parked. In this way, instead of the rear of houses and backyards abutting on the river, a continuous

parkway will add greatly to the appearance of the center of the city.

By the work proposed for immediate undertaking, a channel capacity equal to 40 sec.-ft. per square mile will be provided. In anticipation of greater floods, it was further recommended that, below the section of the river to be immediately improved, land should be appropriated on both sides of the stream for a distance of 4 000 ft., and that in the future when the value of the exposed property justifies the additional insurance and the growth of the city makes the expenditure possible, the river channel should be further enlarged by deepening and widening in this lower section so as to provide for the discharge of the maximum flood through the city without overflow.

It is believed that some such progressive improvement is the only possible solution of the problem of flood control for small cities until the expense can be spread over districts, or the state or federal governments coöperate in the work. It is financially impossible for such communities to provide for the maximum storm, and further, in the majority of cases, such provision would not be economically defensible. Floods are occasional calamities and flood protection is largely a matter of insurance, and the justifiable outlay depends on the ability of the community to finance the improvement and on the risk, including the value of the property exposed and the probable frequency of occurrence of the conditions which will cause damage in varying amounts.

In Tiffin no material damage had been done previous to the storm of last March. Two other floods are recorded, the greater of which did not much exceed 25 sec.-ft. per sq. mile. When the damage done in the flood of this year is spread over the known period during which no such other storm occurred, the yearly loss is not large enough to justify an expenditure sufficient to provide channel capacity for more than one half of the flow recorded in the flood of March, 1913.

In reference to the maximum run-off which may occur on any stream, the fact that there may be a limitation by topographical conditions to the flood-producing capacity is worth considering. Natural flood plain storage is an important

factor, not only in explaining marked variations in the maximum run-off of streams, but also in estimating the possible reduction in flood discharge which may be effected by the construction of artificial storage reservoirs. As a notable example of such a condition, the run-off records in the March flood of the Cuyahoga River in Ohio are of interest. On this stream there are two points where narrow rock channels at the lower ends of wide, flat areas provide natural storage basins, the first at a point where the watershed has an area of 150 sq. miles, the second where this area is 300 sq. miles. These narrow channels and basins have been surveyed and studied in connection with the dam now being constructed for the city of Akron, and the elevations to which the water was impounded were carefully observed during the March flood. As a result of this natural storage the upper basin reduced the run-off at the point where the watershed has an area of 210 sq. miles to approximately 65 sec.-ft. per sq. mile, and the lower basin further reduced the flow to 48 sec.-ft. per sq. mile at the point where the watershed has an area of 350 sq. miles. The rainfall, which was fairly uniform over the watershed, amounted to 9.65 ins. between March 23 and 27. The superficial area of the two basins above referred to is so great in proportion to that of the cross section of the outlet channels that the maximum discharge of the Cuyahoga can never greatly exceed the discharges recorded in the March flood.

In the work at Tiffin it was found that, while there are several available sites on the Sandusky River where reservoirs can be economically constructed, so located that the water held back would effectively reduce the peak of the flood at Tiffin, the cost was altogether beyond the finanical capacity of the city, and only by some combination of interests on the river could reservoir development be made feasible.

Mr. Alvord's description of the type of reservoirs developed in the Columbus investigation is of great interest. It is to be noted, however, that these reservoirs with open sluices extending to the bed of the stream can only be of use in flood prevention, and are not adapted to the improvement of the dry weather flow of the stream or the conservation of the spring flows for

power purposes, both of which conditions would largely help in justifying the expense.

In the Pittsburgh studies, emphasis was laid on the value of the reservoirs in bettering the dry weather flow. Where the latter purpose is served, the question arises as to what portion of the reservoir volume can be assumed to be effective in flood protection. Some well-known authorities have recommended that not more than 50 per cent. of the storage capacity should be considered available for flood control, and others have suggested that only the spillway storage be recognized, and that the depth or prism volume below the spillway should be disregarded. It is, of course, evident that a reservoir, to be most effective, must be located on that tributary from which the flow synchronizes with the peak of the flood at the point on the main stream where protection is being considered, and that a reservoir on a branch, the flow of which naturally arrives before the crest of the flood, may do more harm than good.

As an example of the evils of local channel congestion, the conditions at Tiffin during the March flood are of interest. The Sandusky River runs through the business center of the city, and many buildings facing on adjacent streets parallel with the stream had been constructed out to the lines of the river walls. The width of the channel varied from 140 ft. to 180 ft., and the maximum run-off which could be discharged without some overflow did not much exceed 20 sec.-ft. per sq. mile of watershed. Six highway and one railroad bridge spanned the stream, with one pier in the center of the channel. Also, within the city limits two water power dams of fixed type with 6.5 ft. and 5.0 ft. fall, respectively, were located.

The rise of the river in the 8 000 ft. above the lower corporation limit was 23 ft., or at the rate of 16 ft. per mile, and the velocities during the flood exceed, in certain sections, 15 ft. per sec. The result of this congestion by bridge piers, dams and buildings was to raise the water level about 25 ft. above normal at the upper corporation limit, although the stream did not rise more than 10 ft. above normal at the lower limits of the city. As the maximum depth of water in the business portion of the city was about 10 ft., it is obvious that the damage done

by the flood in Tiffin is largely chargeable to the congestion of the stream within the city limits.

Desmond FitzGerald. — Mr. Alvord has given us a most interesting paper on the serious floods which recently visited Columbus and Dayton. Of course the vital question which the engineer had to answer was, How much water per square mile of drainage area did the freshet yield? The careful investigation which was made showed a flow of about 90 sec.-ft. per square mile and in providing his regulating works Mr. Alvord has considered the possibility of aflow of about 140 sec.-ft.

In September, 1892, I read a paper before the American Society of Civil Engineers in which I called attention to the fact that in New England it might be convenient for the waterworks engineer who is constantly designing waste weirs, dams, etc., to bear in mind that one square mile of land surface yields approximately 1.5 sec.-ft. on the average throughout the year, and that the maximum freshet flow may be one hundred times that amount, or 150 sec.-ft. per sq. mile.

The example which Mr. Alvord has so graphically depicted, and which resulted in such a large loss of life and property, is one which should impress itself on the governing powers of every town and city in the country. Unfortunately, these warnings which nature is constantly offering are almost always unheeded.

How often we see waterways encroached upon by selfish personal interests! As I travel about, I constantly see glaring examples, and I presume every hydraulic engineer has similar experiences. One would think that in laying out municipalities, with all the warnings of the past to aid, the natural waterways would be more respected; but this is seldom done.

People seem to be deaf to any suggestion that disastrous freshets are recurrent affairs or that they are liable to return at any moment. It should be the duty of every municipal engineer to see that the serious consequences of freshets are fully impressed upon his boards who hold the reins of power.

In laying out improvements, ample waterways should be the first consideration. In many instances this can be accom-

plished by treating the banks between low and flood level with landscape effects which cannot be much injured by a sudden flood. Where this economical course is not possible on account of the value of property, a smooth waterway must be constructed, capable of passing the greatest freshet flow with safety, or else storage must be provided for intercepting and equalizing the yield.

MR. ALVORD. — I might say that I think we do not always fully realize that the records of these great floods are very few and cover comparatively a very short time. We have been almost ready to conclude that the fifty or seventy-five years over which definite records have been taken would give us a clue to the great flood; and I think the great flood is so much greater than that estimate that we are misled. If we will look at the flood water channels and the flood plains of our rivers and think that in times past those flood plains were created by great floods we will realize, I think, that the great floods are in all human probability going to cover those plains again some time; and I believe one of the reasons why we underestimate these floods is because we set too much store in a record which is at best far too brief.

MR. FITZGERALD. — It always seemed to me that under these conditions it is the engineer's duty to make his report clear, and phrase it in such a way that it will not be misunderstood. I remember, a number of years ago, I was serving on a commission and a thing of this kind came up. The city had built a dam across the river just above the town and the watershed area was about 300 sq. miles. I was very much surprised, when it was figured out, to find that it appeared that when the freshet came it would wipe out the business part of the city, that being a little lower than the residential part and being covered with very expensive and valuable manufacturing establishments. I told the mayor what my report was to be and he told me that they would not receive such a report. I asked why, and he said: "Because it will practically injure our city. It will injure our credit." I replied: "Well, I think it is my duty to send you that report." He said: "We will never receive it." However I sent it and saw that they

received a copy of it, and I kept a copy myself, which is still in my files.

FRANCIS C. TUCKER (*by letter*). — Just after the spring flood of 1913, I spent some time looking over the damages wrought by that flood in Ohio, Indiana and some other states, and at various times have revisited river-towns that were then devastated. In every such town, improvements that were destroyed by that flood were being replaced in defiance of the proof it afforded that those improvements should not have been built where they were, *without providing other flood-channels.* Many millions of dollars are annually wasted in this way and in the similar occupation of previously unoccupied lands subject to overflow, — enough, if wisely spent, to go far towards preventing these recurrent losses.

The rights of nature and of the public in the natural channels of streams are fairly well understood, and in navigable streams are defined by the laws and courts, but there exist gross ignorance and disregard of the equally manifest rights of nature and the public to the unobstructed flow of the maximum flood-water of *all* streams. That this right of the floods is only occasionally enforced does not cancel it, but the prevalent ignorance concerning this right makes it desirable, and even necessary, to define by law, courts, commissions and public opinion, the right of way the floods have, until otherwise provided for adequately.

Hydraulic laws are easily understood, and, like all natural laws, they do not need lawyers, sheriffs and courts for their enforcement; they enforce themselves. Yet, in every river town the ordinary course of the stream and the flats below high water mark are obstructed and encroached upon by dams, roads, bridges, levees, railroads and buildings without any compensating enlargment of the waterway, although it is plain that obstructions of every nature, placed below the flood level of a stream, will raise the flood height ot that stream and that the better the construction ol that obstacle is, and the more nearly permanent, the more damage the flood will do to something else near.

By lack of proper supervision large damage is being done,

and even the best endeavors of the United States Government and of the states cannot *promptly* handle the enormous problems of flood control by storage reservoirs, levees, or channel-improvements. But most town and county organizations already possess or can acquire power to condemn property for public use, and through judicious use of that power can prevent increased obstruction and consequent increased damages and possible liabilities. This power to condemn land liable to overflow and to limit it to unobstructive uses should be exercised until the flood flow is otherwise taken care of, and every community should do what it can in its own jurisdiction to clear and maintain unobstructed flow of floods until higher authority provides other protection. The probability or certainty of floods should, of course, lessen condemnation values and title be acquired subject to that possibility, except as later changed by act of man.

One of the rights which the United States Constitution tries to preserve is briefly stated thus: "Nor shall private property be taken for public use without just compensation." Should not the converse be held just as true, — Public property must not be taken for private use without due compensation? Applying this rule to the case in hand, no private interest should be allowed to obstruct the flood-flow of any stream until due compensation by adequate channel has been otherwise provided *by the same interest*, or at its expense.

Vol. I MARCH, 1914 No. 3

BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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BITULITHIC PAVEMENT AND WARRENITE ROADWAY.

By G. H. Perkins,

Superintendent of Refineries of Warren Brothers Company.

(Presented December 17, 1913.)

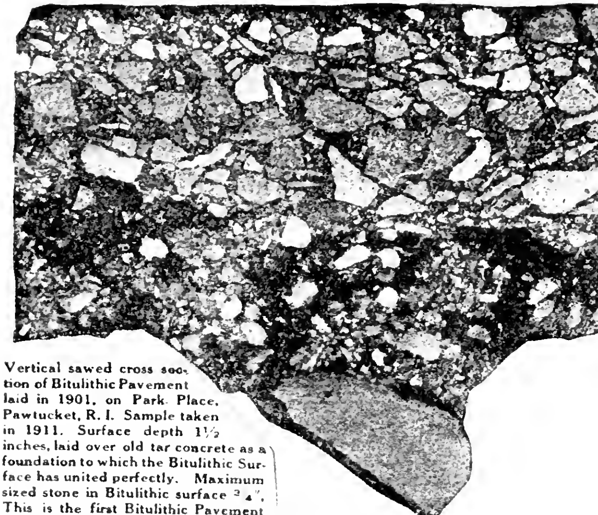
The principles embodied in the construction of bitulithic patents and their application to varying conditions and the bitulithic paving plants are illustrated in Fig. 1, which shows vertical cross-sections of two bitulithic pavements; one being the first bitulithic pavement laid, in Park Place, Pawtucket, R. I., in 1901, the other being from Dartmouth Street, Boston, laid in 1903, the photographed sample having been taken from the work, being from a sewer cut, after nine years' use.

Both pictures in Fig. 1 illustrate the basic principles of the bitulithic patents, the inherent stability of the mineral aggregate, the low percentage of voids and the maximum degree of density.

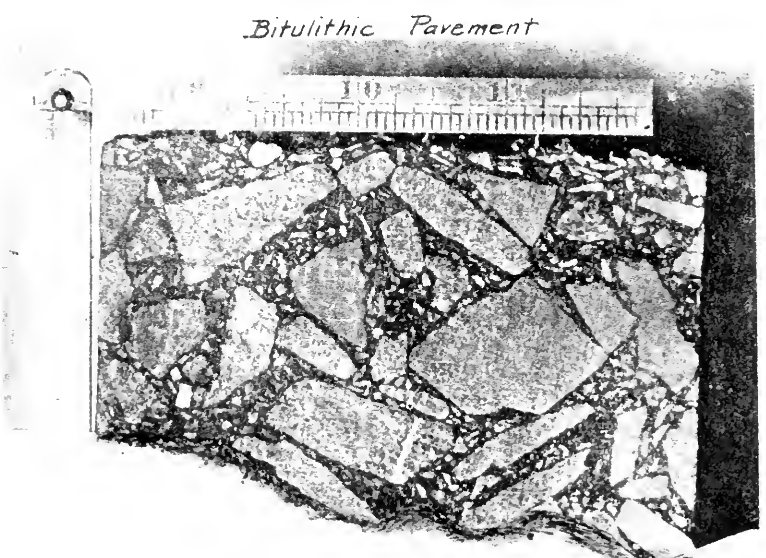
It should be noted that in the upper picture the maximum-size stone is considerably smaller than in the lower picture. The best practice is to use maximum-sized stone whose diameter is equal to about one half the depth of the wearing surface and, receding from that, use finer sizes in such proportions as will fill the voids between the coarser. In the upper photograph the wearing surface was laid on an old tar concrete pavement used as a foundation, to which the bitulithic surface became

Note. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before May 15, 1914, for publication in a subsequent number of the Journal.

Bitulithic Pavement



Vertical sawed cross section of Bitulithic Pavement laid in 1901, on Park Place, Pawtucket, R. I. Sample taken in 1911. Surface depth 1½ inches, laid over old tar concrete as a foundation to which the Bitulithic Surface has united perfectly. Maximum sized stone in Bitulithic surface ¾". This is the first Bitulithic Pavement laid for any city.



Vertical sawed cross section of Bitulithic Pavement laid on Dartmouth Street, Boston, Mass., in 1903. Maximum sized stone in Bitulithic Surface 1¼ inches. Sample taken from sewer cut after nine years' use

RULE! Maximum sized stone approximately ½ the depth of the compressed surface

FIG. 1. BITULITHIC PAVEMENTS.

thoroughly united, the maximum stone being about $\frac{3}{4}$ in. size, or half the depth of the wearing surface.

In the lower picture the depth of the surface is 2 in., being the standard recommended in cases except where the foundation is of solid bituminous concrete to which the bitulithic surface will thoroughly unite and make one solid mass from top to bottom. With the greater depth the maximum size stone is 1 in. to $1\frac{1}{4}$ in. in diameter, and this being the most generally used depth of surface, it represents the more common practice.

The principles referred to under the best practice provide, as Judge Lurton describes it in his opinion in the Owosso case:

> "The particles are made compact in their relation to each other, and there is a minimum of friction in their interactions. The larger pieces of stone withstand the tendency of the small grains or dust to slip by each other and change the form of the pavement by disintegration and lumpy spots, the result being . . . that the mineral aggregate should of itself resist displacement by traffic."

To illustrate this, it is obvious that if one should lay a 2-in. layer of nearly uniform size, small shot on a roadway and attempt to drive a vehicle over it, the shot would roll away from beneath the wheels and we would say the surface had "no inherent stability." In order to hold the shot in position it would be necessary to bind them together with some cementing material such as a hard asphalt cement, but it must be remembered that if this were done the strength of the pavement would depend entirely upon the strength of the cement, as the weight of the traffic would be borne by it and not by the shot.

As an example of the opposite extreme, as far as inherent stability is concerned, we would cite the familiar example of the properly designed masonry arch where each block is truly cut to fit its neighbor so that when the keystone is placed and the falsework removed the arch stands firm entirely independent of any cement between adjacent blocks.

The late Mr. Fred J. Warren, inventor of the bitulithic pavement, realizing that the sand mixture pavements, such as Standard Sheet Asphalt, approached the condition of the imaginary shot pavement to which I have referred, and also realizing that a pavement built of stone on the principles of a cut

stone masonry arch, even if practicable, would be so rigid that it would be noisy, hard on horses, slippery and would abrade rapidly under traffic and in many other ways be objectionable, invented the bitulithic pavement, which consists of large, medium and small size particles of mineral aggregate in proper proportions, all thoroughly cemented together with bitulithic cement. The object of the large stones is to provide a backbone or skeleton for the structure; the spaces between the large stones are completely filled by sucessively smaller sized particles, so that these particles, large and small, key into and lock together to such an extent as to give the mixture the "inherent stability" desired in a pavement, yet do not lock so tightly as in the case of a masonry arch, consequently the inventor has produced a pavement wherein the weight of the traffic is supported by the mineral aggregate and not by the bituminous cement and yet the pavement is resilient and not rigid.

In the case of the imaginary shot pavement where each piece of shot is the same size as every other piece in the pavement, the mixture would contain 44 per cent. by volume of voids or air spaces, to be filled with bitumen.

By following the best practice under the Warren patents as described, the resulting combination of varying sizes of mineral aggregate will contain approximately 12 per cent. of voids to be filled with bitumen, and this low percentage of voids is obtained in daily practice all over the country.

It is impossible for us to formulate a standard screen test or rule as to just what proportion of each size particle of mineral aggregate is required to produce the maximum density or minimum of voids, because the stone from different quarries crush into different shapes, and for this reason it is necessary for us to maintain a corps of laboratory representatives who travel continually from plant to plant setting mixtures to fit the requirements of the available stone supplies as previously determined by careful laboratory test.

After the bitulithic wearing surface mixture has been raked out on the street and thoroughly rolled, but before it has had time to chill, it is covered with a thin coating of flushcoat bitumen which is immediately covered with hot flushcoat stone

chips and these are in turn immediately rolled, thus not only effectually sealing the surface, but also producing a gritty but not rough surface for the pavement.

Fig. 2 is a general view of a semi-portable bitulithic paving plant designed to enable the construction force to carry out these ideas in actual practice. The operation is as follows:

The raw materials, viz., crushed stone, screenings and sand, are fed from the storage piles at the rear of the plant into the cold stone elevators, are heated in the dryers, then elevated to the rotary screen, which is enclosed in a screen house to prevent the dust scattering over the neighborhood. This screen consists of the several sections which are required to separate the mineral aggregate into the various sizes. The hot stone passing each of these screen sections drops into its own compartment in a sectional bin and is thus kept separate from other sizes. The "boxman" weighs out the amount of each size required into a weigh-box supported on platform scales with a multiple beam which enables him to weigh each size separately and accurately.

While the weighing is taking place the mixer-man has filled the bitumen bucket with the required weight of bitulithic cement by dipping from the melting tanks, the weight of bitumen being accurately measured by scales on the bucket carrier. The bitumen and mineral aggregate are then emptied into the mixer and thoroughly mixed until all particles are completely coated and the mass has been transformed into an uniform bituminous concrete, when the slide under the mixer is opened and the batch dropped into the wagon waiting under the platform.

Some of the important points in our methods are:

First, the laboratory makes tests to insure that the raw materials are of suitable quality.

Second, the laboratory makes tests to ascertain just what proportions of each size of mineral aggregate should be used to produce a pavement mixture of the greatest density and to determine the amount of bitumen required.

Third, we provide the construction force with a plant which can and will produce commercially, a uniform mixture in accordance with the formula set by the laboratory.

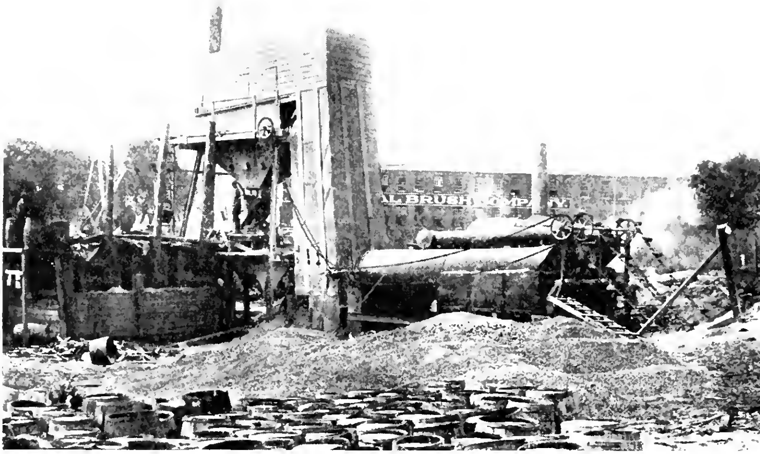


Fig. 2. Semi-portable Plant.

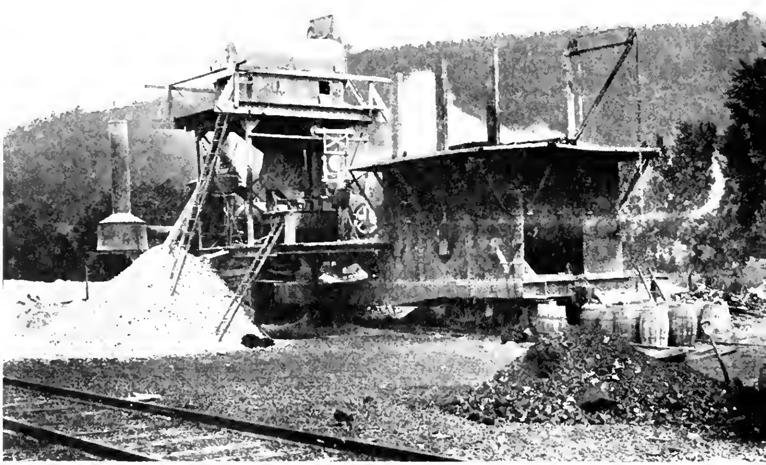


Fig. 3. One-car Railroad Plant.

Fourth, as a check, daily samples of the pavement mixture and bitumen as used are sent to the laboratory, where they are analyzed to ascertain whether the instructions have been carried out.

Fig. 3 shows a standard one-car railroad bitulithic paving plant which embodies all of the features of the semi-portable type and in addition has the advantage of being built on a single steel car and therefore can be more quickly erected ready to run after arrival at destination. In addition to this the mixing platform overhangs the side of the car, so that if the ground surrounding the plant will allow it, the wagons can be driven under the mixer from the rear, thus avoiding the delays due to "backing under." There are three large kettles, two for melting and one, next to the mixer, for use as a dipping kettle, this kettle being covered and provided with an air-tight manhole cover so that the bitulithic cement may be forced with compressed air from it to the bitumen weigh-bucket. The dial of the scales has two movable stops which are placed at the proper points for the weight of the bucket empty and full, which enables the plant foreman to tell at a glance whether the mixer-man is weighing accurately or not. These scales and the stone scales are tested daily with three standard "test weights" in order to detect as soon as possible any lack of adjustment.

The Warrenite roadway has been designed to do for country roads what bitulithic has done for city streets, and Fig. 4 shows cross-sections of three pieces of Warrenite roadway mixture made of very different materials. The upper section was made by using traprock, the next gravel, and the lower one crushed oyster shells, and show what can be done with such materials when as in some cases they are more available than crushed stone.

Where a road has been constructed of oyster shells and the depth is sufficient, a Warrenite road may be made by removing about 2 in. of the old metal, screening it to enable close proportioning of sizes and heating and using the old shells in the new Warrenite surface with a portable plant located on the road.

The principles used in formulating the proportions of each size particle of mineral aggregate to be used in designing the

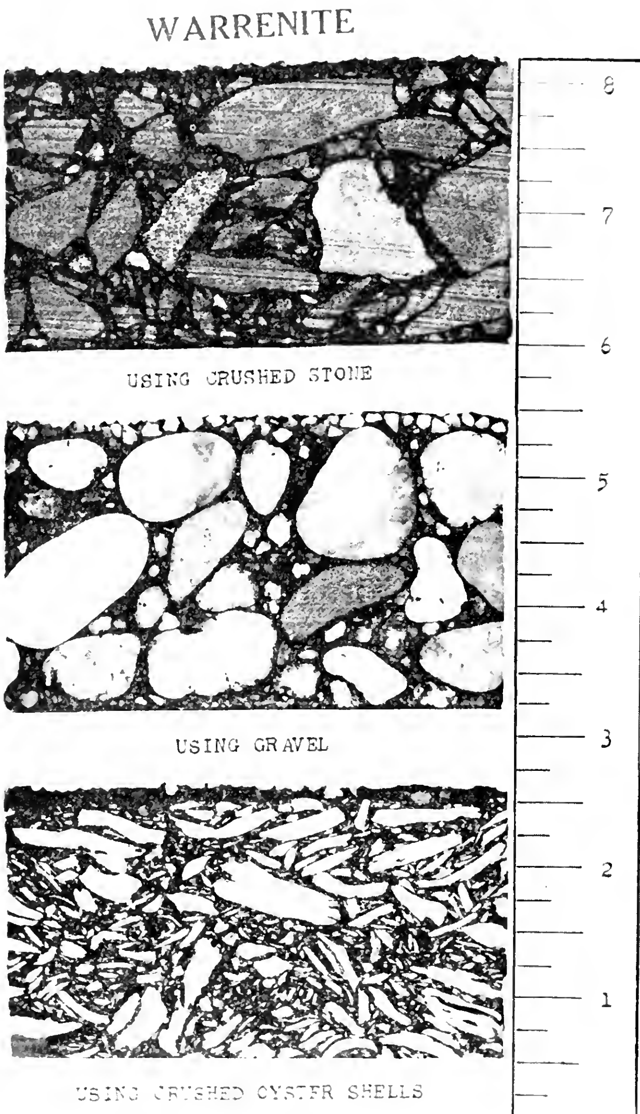


FIG. 4. SECTIONS OF WARRENITE ROADWAY.

Warrenite surface mixture are the same as those used in bitulithic, and are the same in all cases irrespective of whether stone, gravel or crushed shells are used as mineral aggregate.

After the mixture is laid on the road it is flush-coated with bitumen, stone chips or coarse sand are spread and rolled the same as in case of bitulithic, and the road immediately thrown open to traffic.

When the demand for improved country roads of high-class bituminous type came up some years ago, it was realized that it

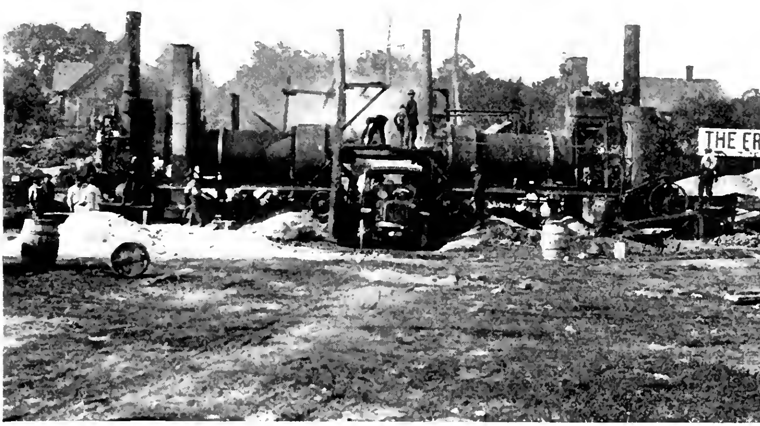


FIG. 5. PORTABLE PLANT.

would be necessary to provide a portable plant, one which could be set up in a gravel bank or alongside the road where railroad sidings are not available. To accomplish this, after a vast amount of experimentation, Mr. H. W. Ash, mechanical engineer of Warren Brothers Co., invented the portable plant, two of which are shown in Fig. 5, headed toward each other so as to deliver mixture simultaneously from both plants to the motor truck in the center.

While the mixture produced by these plants is much like bitulithic, the methods by which it is obtained are radically different from those in use on the bitulithic plants. The crushed stone, screenings and sand are placed in separate piles, and the required proportion of each size as previously determined by laboratory test is measured into the drying section of the plant and there remains until dried. One full batch of mineral aggregate measured in this manner is fed into the elevator and raised to the hopper. After the entire batch is in the hopper the gate in the chute allows it to descend into the heater drum, which is heated by an oil flame through the combustion chamber. While the batch is being heated it is slowly forced forward by spirals inside the drum toward the mixing chamber. When it is hot enough a gate or chute suspended between the heating and mixing chambers of the drum is tilted and conveys the entire batch into the mixing chamber, where it is thoroughly mixed with Warrenite cement poured in through a funnel above the platform. The bitumen is weighed accurately in a bucket on spring scales, the same as on a bitulithic plant. When the batch is mixed it is delivered into the wagon by another tilting chute at forward end of the mixing chamber.

While one batch is going through this process, other batches have been successively started, so that at any one moment there are, — one batch in the mixer, one in the heater, one in the hopper and one being measured in wheelbarrows; yet on account of the design of the plant each batch is kept entirely separate and distinct from every other and for that reason it is possible to control the mixture and keep the proportions of the various sized particles of the mineral aggregate constant and uniform.

Quite frequently, after having endeavored to explain the basic features of the Warren patents and mixtures, we are asked: "Well, what is the difference between your pavements and others, anyhow?" and to answer that question as simply as possible we have had Fig. 6 prepared.

As will be seen from the labels, the four upper pictures are of sawed cross-sections of Standard Sheet Asphalt at the left, which was the standard city pavement before the invention of

bitulithic, which is shown at the extreme right, while in the center are shown the two most popular attempts to produce a substitute for bitulithic and still not infringe our patents.

The lower row of pictures are of four square glass jars of exactly the same size, in which have been placed the mineral aggregate, which was extracted in each case from a 12 cu. in. block of pavement.

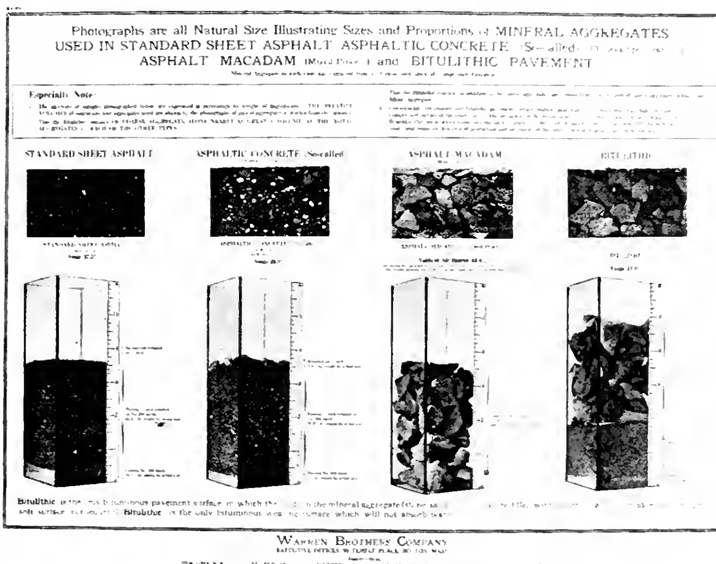


FIG. 6. RELATIVE QUANTITIES IN DIFFERENT PAVEMENTS.

In order to show the relative amount of coarse and fine material in each case, the mineral aggregate has been divided into three sizes:

First, that which is larger than $\frac{1}{4}$ in. screen.

Second, that which is smaller than $\frac{1}{4}$ in. but larger than will pass a screen having two hundred meshes to the linear inch.

Third, that which will pass a screen having two hundred meshes to linear inch.

The percentage of each of these sizes when measured by weight is shown in figures at the side of the jars.

The relative volume of each size is of course shown by the height of each layer as measured by the 6-in. rule at side of each jar.

By referring to the figures it will be seen that the four pavements compare as follows:

	Standard Sheet Asphalt. Per Cent.	Asphaltic Concrete Topeka. Per Cent.	Asphalt Macadam. Per Cent.	Bitulithic. Per Cent.
Retained on $\frac{1}{4}$ in.	None	5.5	100	57.6
Passing $\frac{1}{4}$ in., on No. 200	89.2	87.5	None	38.2
Passing No. 200	10.8	7.0	None	4.2

In other words, the four mixtures might be summarized as follows:

Standard Sheet Asphalt is an asphaltic mortar; all of it is finer than $\frac{1}{4}$ in. and consists of "all sand, no stone."

Asphaltic Concrete (so-called) is also an asphaltic mortar, consisting chiefly of sand with a little stone. It is in no sense a concrete, although it is frequently given that name. The specifications require that all of the mineral aggregate shall pass a $\frac{1}{2}$-in. screen and that less than 10 per cent. of it shall be larger than $\frac{1}{4}$ in.; therefore it cannot be a concrete as the larger particles are so few in number, they are scattered about like currants in a fruit-cake, and cannot possibly add to the strength or stability of the structure.

Asphalt Macadam consists of all stone, no sand. The stone is of practically uniform size, therefore as shown in upper photo there are no small pieces to fill the voids between the large stones.

Bitulithic is a true bituminous concrete in which the coarse aggregate, i. e., the stone larger than $\frac{1}{4}$ in., forms the major portion of the structure.

By comparing the materials in the several jars it will be seen that this coarse aggregate alone of the bitulithic is 3 in. in height, or almost as much as the entire aggregate of each of the other mixtures, which all average about $3\frac{1}{2}$ in. in height.

All of the finer aggregate of the bitulithic finds its place in the voids between the coarser particles when it is mixed and laid,

therefore it will be seen that in the bitulithic on the street there is approximately 60 per cent. more aggregate in a square yard than in the best of the other types when laid to the same thickness. This fact accounts for the greater density, stability and low percentage of voids in the bitulithic. The voids in these four samples were determined and found to be as follows:

	Per Cent.
Standard sheet asphalt	27.3
Asphaltic concrete (so-called)	29.8
Asphaltic macadam (mixed process)	44.4
Bitulithic	11.8

While of course these figures refer to these particular samples, they are typical average specimens of these four types, selected from actual work, without bias or prejudice to show actual comparison.

Vol. I MARCH, 1914 No. 3

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PAPERS AND DISCUSSIONS

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COST ACCOUNTING ON CONSTRUCTION WORK.

With a Description of the System used by the Aberthaw Construction Company.

By Leslie H. Allen, Member Boston Society of Civil Engineers.

(To be Presented March 25, 1914.)

Introduction.

The problem of cost accounting on construction work is one that has not received the amount of attention and study that its importance warrants. When we consider the vital importance to the contractor on construction work of a knowledge of the cost of his work, it is surprising to find that only a few contractors have succeeded in finding out in detail what the unit costs of their work are. Most of the big commercial enterprises make a point of figuring very carefully their cost of production, but building and engineering contractors seem content to go on in their old ways, with only a hazy idea how their work is coming out, and no definite knowledge as to the amount of profit or loss made until the job is completely finished and paid for. Mr. Sanford Thompson, in his book on "Concrete Costs," asserts that "as generally practiced, cost keeping is so approximate and inaccurate as to be of comparatively little value for estimating or for immediate use," and later on he states that estimates of labor costs are frequently mere guesses, because

Note. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before May 15, 1914, for publication in a subsequent number of the Journal.

"the contractor does not know with any degree of accuracy the time and cost of doing each kind of work." I venture to assert that not more than ten per cent. of the contractors in Boston doing work on a ump sum basis could tell within one thousand dollars what their profits or losses are on their unfinished contracts now in hand.

It is not hard to find a reason for this state of affairs. The old-time superintendent of construction was usually a mechanic who by reason of special ability had risen to the command of men and become a superintendent. These men, of whom many are still with us (and doing excellent work), are men to whom figures and costs meant very little. They relied for success on their innate common-sense and their ability to drive the men under them, and although they made mistakes, some of which would have been self-evident if they had studied costs carefully, yet they did excellent work and achieved results not to be despised even in these days of scientific management, cost accounting and complex organizations of one sort or another. Such men, however, took no interest in cost accounting, and if directed to furnish cost figures took very little care to see if they were made up rightly or not.

Another reason is that there is often a lack of definite instruction given from the office as to how costs are to be kept, and that no man who has studied the problem and knows definitely just what is wanted is in charge of the work and personally responsible for it. The timekeeper on a construction job is a very busy man. Often he has materials to order and check, and many other duties to perform, and has no time to think out the details of a cost accounting system for himself, and he contents himself with as little work in subdivision of payrolls as his experience tells him will "get by." Then when his reports come in they are handled by clerks who do not understand them and who do not make any effort to correct them as they go through, and the cost-accounting system becomes unreliable and one is told that "it is impossible to keep accurate costs on construction work."

It is probably true that every contractor and builder has made some attempt to find out the unit costs of the work

he does. Some contractors have got a system that really gives them the information they need. Many firms have a cost-keeping system which tells them approximately what their unit labor costs from week to week are, but takes no account of materials and gives them no idea as to how the whole job stands financially. Such men have no real idea as to whether their jobs are profitable or not until the bookkeeper's statement at the close of each job shows the actual profit or loss made. Many have tried to keep up a cost-keeping system but have thrown it up owing to its difficulties and inaccuracies, and rely simply on their bookkeepers to tell them how much expense has been incurred on the job, while their eye tells them how much of the job is done. The writer remembers in his earlier days being directed to visit half-completed jobs for which he had made the estimate and make a survey of same for comparison with the bookkeeper's statements, and this was the only way known by his firm at that time of comparing estimated costs with actual costs to see what profit or loss had been made, although at that time a system of reporting weekly costs was being used similar to that outlined above.

With the change of the times and the change in contractors' methods, the attitude of the contractor to cost accounting systems is changing, too. The old-time superintendent is giving place to the technical graduate who is a man with engineering training accustomed to view the situation from all sides and relying on actual cost figures rather than on his own judgment to tell whether his work is efficient. Modern competition is becoming so keen and work is taken on such a small margin of profit that it is of vital importance that every item of the work be kept down to its estimated cost, and cost keeping is fast becoming a necessity to all who wish to make a profit out of contracting on construction work.

The purpose of any cost-accounting system is threefold, — first, to watch the job from week to week to see if the work is being carried out economically; second, to see whether the cost is above or below that of the original estimate; and third, to furnish information for future use in estimating and in supervising work in progress. In other words, first, to determine the

items of prime cost and the unit prices of these items; second, to discover what relation these bear to a predetermined selling price; third, to establish new selling prices for future work. The relative importance of these three items is in the order given.

The problem before the contractor's accountant is an entirely different one from that of the bookkeeper or the factory cost keeper. A good deal of the dissatisfaction and incompleteness of many existing systems is because the problem has been approached from the financial point of view rather than the engineer's. I think it was Mr. R. T. Dana who was the first to insist that cost keeping was not a bookkeeper's job and could not be satisfactorily handled by the man who kept the firm's books. This is so. The bookkeeper's viewpoint is the financial one, and deals with totals and balances of cash. The cost accountant's viewpoint is an engineer's, and deals with unit costs and quantities of materials. The two cannot be satisfactorily held by one man unless he has had a thorough training both in bookkeeping and engineering lines. Such a training is rare. The primary object of the cost keeper in a large factory or mill is to determine the selling cost of the articles, and therefore every item of expense burden incurred in carrying on the factory is prorated or apportioned to the cost of the articles produced for sale. The contractor's selling cost is determined beforehand and he is faced with the problem of so splitting up his selling cost that he has a proper appropriation for each item of expense, the very reverse of the factory's accountant's problem. It is for this reason that I have placed prime cost first as being the most important, and selling cost last as of least importance.

The estimate of cost on which a contract is taken is more like the budget appropriation of our government, which having a predetermined amount of money to spend proceeds to allot as much as is possible to each government department in proportion to its needs, the total of such appropriations being equal to the amount of the estimate of cost.

The contractor's cost accounts, if they are to be of any use, must show not only the amount of money spent in the work, but the way in which it has been spent; and this cannot

be shown if items of general expense, such as plant, watchmen, etc., are all distributed among the items of excavation or concrete. The result may be financially accurate but uninforming to the contractor. For instance, on the cost accounts on the Panama Canal which appear in the *Canal Record* which most of the members see, it will be noted that the cost of plant, track, forms and general expense, etc., all are worked out in terms of per cubic yard of concrete. This is correct from the financial viewpoint, and the result shows the cost of the concrete to the government. But it does not tell an engineer whether the work is being done efficiently or not. He wants to know the cost of setting up and repairing the plant, the cost of handling the material, the detailed cost of form work, while general expense is meaningless to him unless he knows the details. When the cost of moving tracks, repairing plant, etc., is reported at so much per cubic yard as a subdivision of excavating cost, the cost of the operation cannot be criticised. It is very necessary that this distinction be kept in mind and that costs should be worked out from an engineer's standpoint rather than from a bookkeeper's or an accountant's standpoint. The information turned out by the cost-accounting department should not only show results but should give information showing the reason why the results are so.

In the writer's judgment, the cost accounting on construction work should be handled in connection with the estimating department rather than in connection with the bookkeeping department. The estimator should know best what information he requires from a job to check up the work he has estimated, and into what units the costs should be divided. He is then enabled to keep closely in touch with actual work in progress and compare with his estimate from time to time.

The method usually employed by contractors in their cost accounting is to divide up the time spent on the job under certain fixed headings, such as excavation, brick work, mason work, concrete work, carpentry, and so on, and to make a report of the quantity of each kind of work executed, and to work out from same either daily or weekly the unit labor costs; at the close of the job, to work these up into totals and also to work up at this

time the cost of all materials into units and combine them with the labor costs, giving the total cost of labor and material on each item of the work. This works well in some offices as far as it goes, and shows whether each week's work was efficient and economical. But if no account is kept of material until the job is closed, and no check is taken on quantities reported by the men on the job, and no comparison is made with the estimate, its value is not very great. In the system used by the Aberthaw Construction Company, we have added from time to time the following features which do not appear in most accounting systems. First, in addition to the weekly labor costs, the average labor cost on each item to date is figured. Second, a periodical check on the quantity report is made. Third, we use a standard mnemonic code revised to suit the requirements of each job. Fourth, an accounting of material is kept up from month to month. Fifth, an analysis of the estimate is made for comparison with the weekly costs. Sixth, a monthly balance is struck, showing profit or loss to date. Seventh, a "field sheet" is furnished to the timekeeper, which enables him to keep track more regularly and systematically of the men at work.

It is the purpose of this paper to describe the Aberthaw Company's system in detail, taking up in logical order the above points and matters incidental thereto. The present system was not invented in a day but has been a gradual development. The cost-keeping system was installed early in the history of the company by Mr. Wason, the president of the company, who laid work out upon the usual lines adopted by other contractors as indicated above. The above additional features have been added since the beginning of 1910 in the order indicated above, and the complete system may be said to have been in working order for over two years, long enough for us properly to try it out and to know that it really gives us the information we need. In other words, the system I am about to describe is not the dream of a theorist but something that is really practicable; that is not expensive in operation and that any contractor can use if he has but the patience to study his problem and insist on getting just the results he wants.

Although the writer's firm specializes in one branch of construction work, the system is equally applicable to any other work of similar nature, whether in the line of heavy engineering or the building of modern office buildings or frame dwelling-houses.

Section I.

THE ANALYSIS.

At the start of a job, an estimate is made of its cost in the usual way. This estimate is then analyzed to show its component costs. Fig. 1 shows an estimate on a small job executed by the Aberthaw Company this year. Figs. 2 and 3 show the analysis of the same. This analysis is almost self-explanatory but it will be well to call attention to one or two points in it. It will be noted that the seven items of concrete and finish in the estimate have been resolved into nineteen items in the analysis, and the seven items of forms in the estimate have been resolved into eleven items in the analysis, and so on, each item being resolved into its component parts, and where these parts are alike in two items adding them together. For instance, concrete labor in footings appears by itself, but the cement, sand and stone are added to those in the columns and floors. By adding together, it will be found that the seven items of concrete in the estimate have the same total cost as the nineteen items in the analysis.

This analysis is used as a basis of comparison during the life of the job, and the original estimate is not referred to at all. This is different from the general practice, as it is usual to build up the units of labor costs on a job in a synthetical manner to compare with the estimate, rather than to analyze the estimate to compare with the units on the job. This is a very important feature of the system and is a solution of one great difficulty. The usual method is to try and build up the price of each item from the information on unit costs given, so as to compare it with this item in the estimate. Take, for instance, the item of concrete. The price of concrete is compiled by reckoning up the labor of unloading cement, sand and stone and the cost of these materials, and also the labor of

Estimate No. 1210 **ABERTHAW CONSTRUCTION CO., BOSTON** Sheet No.
Job No. 1990

Summary of Estimate

May 17th 1913

Concrete footings 1:2½:5		246 cu yds	6.00	1476
" columns 1:1½:3		169 "	7.50	1268
" floors & wall beams 1:2:4		690 "	6.60	4554
" window sills		629 ft lin	25	157
Cinder concrete crickets on roof				25
2" Cinder concrete fill between screeds		20940 sq ft	03	628
Rubbed external finish on concrete				300
Forms to footings		4573 sq ft	10	457
" " internal columns		3037 "	15	456
" " external columns		7300 "	15	1095
" " internal column heads		70	4.50	315
" " external column brackets		55	1.00	55
" " mushroom floor slabs		28618 sq ft	10	2862
" " wall beams		3918 sq ft	12	478
" " window sills		629 ft lin	20	94
Steel reinforcement, plain round bars	base sizes	20 Tons	43.00	860
	¼" slab bars	21 "	48.00	1008
	sundry steel	5 "	46.00	230
	¼" spirals	2½ "	80.00	200
Inserts		1000	15	150
Riveted bearing plates in footings		17	3.00	51
Brickwork 8" curtain walls in Flemish bond		1200 f.c.	55	660
Cutting toothing & patching old walls adjoining				50
2" Wire lathed & plastered both sides partition		18 sq yds	3.00	54
Hard pine posts framed in to support old building		2 M	80.00	160
Repair old floors where old building adjoins new				250
Pine Stairs & enclosure 1st Floor to Basement				35
Pine railing				50
Miscellaneous cast iron work				436
" wrot iron & steel work				341
Tinned doors & hardware & erection		2	30.00	60
Steel sash including glass and glazing		5260 □'	43	2270
erection of same			05	263
Excavation over site		100 c.y	50	50
" for trenches for footings etc		553 c.y	80	442
Spruce sheet piling to trench		10 M	50.00	500
Grading				100
Clean up the job and clean glass				100
Travel, board & superintendence				300
Liability Insurance				400
Contingencies & sundries				400
Total Estimated net cost, excluding profit			$	23640

Fig. 1

mixing and placing and finishing the concrete and the cost of the tools and plant. (I do not mention forms, which I regard as an entirely distinct and different item.) If at the end of a month 500 cu. yd. of concrete have been placed and material enough to mix another 600 cu. yd. is on the ground and all the plant is set up, it will be a very difficult matter to

determine exactly how much labor and material should be charged to work that is done and how much is chargeable to future work. If all the masons' staging is erected and only one third the brick work done, the cost of brick work will be unbalanced in the same way. To solve this difficulty, we use an analysis of the estimate and keep the costs on each item of the

Job No. 1990 **ABERTHAW CONSTRUCTION CO.** Sheet No. 1

Analysis of Estimate

		Labour		Materials & Sub Contracts	
Concrete					
Labour in footings	246 c.y.	1.00	246		
" " columns	169 "	1.50	254		
" " floors & beams	690 "	1.00	690		
" " window sills	629 ft.	.15	95		
" " cinder concrete crickets			20		
" " cinder concrete fill between screeds including laying screeds finished by owner	125 c.y.	2.00	250		
" Rub with carborundum			300		
Plant erect & repair			250		
" dismantle			50		
" freight					150
" rental					300
" small tools & supplies					450
Cement	2000 bbls			1.75-.40 1.35	2700
tests				.03	60
Unloading, teaming & loss on MTS				.05	100
Sand	520 c.y.			.80	416
Crushed stone	1400 tons			1.40	1960
Cinders	130 c.y.			.50	65
Concrete sundries					52
Forms					
Labour in footings	4580 sq. ft.	7.00	321		
" " floor slabs	28618 "	7.00	2005		
" " wall beams	3981 "	9.00	359		
" " external columns	7300	11.00	803		
" " column brackets	#55	.70	39		
" " internal columns & heads				Sublet	771
" " window sills	629 ft.	.15	94		
Lumber, nails, & oil etc.					1070
Unloading & handling lumber			50		
Sawmill			100		100
Detailing forms in Boston office					100
Steel Reinforcement	46 Tons			37.00	1702
Spirals	2½			60.00	150
Tests					10
Unloading	48½	.50	24		
Wire & sundries				.50	24
Bend & place	48½ "	8.00	388		
Rivetted bearing plates in footings	#17			3.00	51
Inserts	#1000	.05	50	.10	100
			6388		10331

Fig. 2

analysis separately. The estimate is put away and never referred to again, and all comparisons are made with the analysis. You will see when I describe the monthly statement how easily

Job No. 1990 — ABERTHAW CONSTRUCTION CO. — Sheet No. 2

Analyses of Estimate Cont'd

		Labour		Materials & Sub Contracts	
Brot forward			6388		10331
Brickwork	1200 ft	20	240	35	420
Cutting and patching old brickwork			25		15
Metal lathed & plastered partition			24		30
Hard pine posts			50		110
Repair old floors			200		50
Pine Stairs & enclosures			20		15
Pipe railings			10		40
Miscellaneous cast iron work			36		400
" wrot			70		271
Tinned doors & including erection	2			30.00	60
Steel sash including glazing	5262 sq ft				2270
Erection		05	263		
Excavation over site	100 c y	50	50		
Excavation for footings	553 c y	80	443		
Spruce sheet piling	10 M	15.00	150	35.00	350
Grading			100		
Clean up the job & clean glass			100		
Travel board & Superintendence					300
Liability Insurance					400
Contingencies & Sundries					400
			8178		15462
Net Total			$ 23640		

Fig 3

this takes care of difficulties like those referred to or to unfinished work. It is not until the job is completed and the books are closed that I make a synthetical summary showing what

a cubic yard of concrete or a cubic foot of brick work has cost.

I lay stress on this because the difference between analysis and synthesis in accounting is vital, and it is my belief that it is not possible to get a clear and accurate idea of the fluctuations of cost on construction work by a synthetical method, because labor and material and overhead expense are so distributed that they cannot be properly identified or criticised. It will be noticed that labor and material are kept in separate columns in the analysis and are kept entirely distinct all through the job. For accounting purposes, material includes subcontracts, insurance, traveling expenses, electric power, etc., and in fact everything except labor and teams. Teams when hired by the day are reckoned as labor, but teams working under contract, at an agreed price per load, per yard, etc., are reckoned as subcontracts and kept in the material account.

On the work of most contractors it will be found that the amount and cost of the materials will not vary very much, and, except for checking consumption of cement, coal and lumber, the profit or loss made on materials at the start of a job will remain steady all through. But the labor does fluctuate exceedingly from week to week. It is on the labor side that most of the losses or profits may be expected. In this paper and in the writer's firm a good deal more attention is given to the labor side than to the materials. At the same time the material must not be overlooked, as wasteful use of cement, lumber, etc., may run the cost of a job up unexpectedly, to say nothing of the need of a periodical check, if there is any suspicion of graft among subordinates.

We furnish a copy of the analysis in note-book form to the superintendent on the job as well as to our general superintendent and to the heads of the firm. This is particularly useful to the job superintendent as he knows what the office expects him to accomplish in the way of costs. If his judgment on costs is not sound, it tells him what the items of his work ought to be done for.

Section II.

THE CODE.

Having analyzed the estimate, instructions are made out for the timekeeper in the form of a code, Figs. 4, 5 and 6. This code is made up from the standard mnemonic code used by the author. The code differs from that used by other contractors only in the fact that the mnemonic principle is used instead of numbers, and that the divisions of time have been carried a good deal further than is usual. Although this does not seem to be an important item in itself, it is so because it simplifies the work of the timekeepers on the job to a very large extent, and insures more accurate and intelligent reports being made from the job.

All contractors who have attempted any cost keeping will agree on the necessity for some sort of a code to report work done, not on the ground of secrecy but to obtain concise, quick descriptions. It has been found that if timekeepers are simply told to report the work done and describe it, their descriptions will be misleading and verbose, and in going their rounds they will probably make up a code for themselves which afterwards they have to turn into a written description.

It may be worth while to spend a little time in explaining the principles of the mnemonic code used. The initial letter is always a capital and indicates the kind of work to be done. For instance, M stands for concrete Masonry, F for Forms, R for Reinforcing Steel, S for Structural Steel and miscellaneous iron work, B for Brickwork, and so on. As far as possible the initial letters chosen are mnemonical, that is, they are the first letters of the items they represent. The second letter is always a vowel and indicates what is being done in the division of work which it is describing; "a" stands for making items before setting, and "e" stands for erecting or setting or fixing in place; "i" stands for stripping or removing or pulling down; "o" stands for repairing or patching; "u" is a general utility item standing for unloading and other similar items. It will be seen that these are mnemonic in that each vowel is the vowel sound of the word that it represents. The third letter, which is always a consonant, indicates mnemonically the place or part of the

STANDARD TIMEKEEPING CODE.

MAIN DIVISION — Kinds of Work.

Initial Letter:

P Plant.
D Digging, earthwork and rock-work and items in connection.
M Concrete.
F Forms.
R Reinforcement.
K Finish of concrete surfaces.
C Finish carpentry (windows, flooring, etc.) and any carpentry not belonging to P, D or F.
S Miscellaneous steel and iron work and other metal work.
B Brick masonry, stonework, tile, Akron pipe, etc.
Z Miscellaneous.
X Extra work (prefix to any of above).

SUBDIVISION — Kinds of Labor.

Second Letter (for all main divisions except D and K):

a Making or preparing, viz., making up forms, mixing concrete, bending or fabricating steel, etc.
e Erecting, placing or building, viz., erecting forms, placing concrete, laying brick, fixing sash, etc.
i Removing, stripping or cutting away, viz., stripping forms, cutting away concrete or brick, etc.
o Repairing, viz., patching voids in concrete, repairing mixer, etc.
u Receiving, unloading, piling, loading, etc., viz., receiving cement, sand, lumber, etc., unloading and storing same, unloading plant and reloading at close of job, etc.

Second Letter with D:

a Excavate.
e Backfill.
i Pumping.
o Grading.
u Drilling and blasting.

Second Letter with K:

a Picking.
e Plastering.
i Rubbing with carborundum.
o Repairing, filling voids, cleaning floors, etc.
u Granolithic finish laid integral with the slab.
ua Granolithic finish laid after concrete has set.
y Cement wash.

FIG. 4.

building in which the work is done, that is, "f" indicates floors, "c" columns, "b" beams, "k" cornice, "l" lumber, "d" doors, and so on. As far as possible these are mnemonic, but it is not possible to make every item so, and some consonants have to be arbitrarily chosen to make out. As the standard code is

STANDARD TIMEKEEPING CODE.

SUBDIVISIONS — Location of Work in the Building.

Third Letter (for all main divisions except P, S and C):

b	
bc	Belt course.
c	Columns.
ch	Column heads (mushroom).
cc	Cinder concrete.
d	Footings.
dp	Drain pipe (tile).
f	Floors.
fs	Floor slabs.
fb	Floor beams (beam construction).
fm	Corrugated metal to slabs.
g	
h	Cellar or basement.
j	
k	Cornice.
l	Lumber.
m	Monitor or pent house.
n	Lintels.
p	Paving or sidewalk.
q	
r	Rubbish.
s	Stairs.
t	
v	Vault lights.
w	Walls.
rw	Retaining walls.
ws	Window sill.
cw	Curtain walls.
x	Cement.
y	Sand.
z	Stone or gravel.

Third Letter with C:

c	Column.
d	Door.
df	Door frame.
dt	Door trim.
f	Floor.
fb	Floor beam.
fs	Floor screed.
fp	Sub-floor plank.
ft	Top floor maple.
g	Gates.
h	Hardware.
ho	Operating gear.
j	
k	Cornice.
l	Lumber.
m	Monitor or pent house.
ms	Monitor sash.
n	Lintels.
p	Partition.
pl	Platform.
r	Roof.
rb	Roof beam.
rp	Roof plank.
rt	Roof truss.
s	Stairs.
t	
v	
w	
x	
y	
z	Miscellaneous.

FIG. 5.

the same on every job and is used simply with adaptations to meet the requirements of the work in hand, these arbitrary symbols are quickly learned. It will be noticed that the third letter has to be a different one in the case of items relating to plant.

It should be an easy matter to revise this code to apply to any other sort of construction work, or to industrial work of any kind, bearing in mind the general principles on which it is framed.

STANDARD TIMEKEEPING CODE.

SUBDIVISIONS — Location of Work in the Building.

Third Letter with S:

b I-beams, channels, etc.
c Columns.
cb Column bases.
d Doors.
dg Door guards.
df Door frames.
ds Door sills.
fl Flashing.
g
h
j Bolts.
k Cornice.
l
m
n Lintels.
p Pipe.
q
r Railings, gratings, etc.
s Stairs.
sr Stair rails.
sl Sleeves.
t Trusses.
v Inserts for sprinklers, etc.
w Windows.
ws Window shutters.
wg Window guards.
x
y
z Miscellaneous.

Third Letter with P:

b Boiler.
c Crusher and elevator.
ch Chute.
d Derrick.
f
g Locomotive, portable engine and boiler.
h Hoisting engine.
j
k
l Elevator tower, bucket and hoist.
m Mixer and engine.
n Temporary buildings.
p Pump.
q
r Runways, staging, ladders and guard rails, etc.
s Wood-working shop, saw bench, planes, etc.
t Track.
v
w Water supply.
x
y
z Miscellaneous.

FIG. 6.

Although at first sight it looks complicated, yet it has been found to be very simple in practice, and new timekeepers and superintendents very quickly pick up its essentials.

It has the advantage that if any work is done on the job which was not known of or contemplated when the original code was made out, it is a simple matter to adapt the letters and make up a fresh code word for the new work. As a matter of precaution, we always require our timekeepers to give the explanation of a new code word whenever he makes one up, although very often we can read them without such explanation, owing to our familiarity with the principles on which the code is based.

From the standard code as given above, a special code is written out in the head office for the job before the work is started, and from time to time additions are made from the office or by the job, to meet special items of work met with on the job; but all the main items of work, such as concrete in columns and floors, forms, and reinforcement, have the same code word at all times, for example.

M — CONCRETE.

	Mix.	Place.	Fill Voids, Smooth Up, Etc.
Footings,	Mad	Med	Mod
Floors and Roof,	Maf	Mef	Mof
Columns,	Mac	Mec	Moc
Walls,	Maw	Mew	Mow

F — FORMS.

	Make.	Erect.	Strip.
Footings,	Fad	Fed	Fid
Floors and Roof,	Faf	Fef	Fif
Columns,	Fac	Fec	Fic
Walls,	Faw	Few	Fiw

SECTION III.

THE TIMEKEEPING.

A. The Field Sheet.

On the job the timekeeper is supplied with what we call a "field sheet," an example of which is shown in Figs. 7 and 8. This field sheet is, we believe, an innovation in timekeeping. A

fresh sheet or sheets is used every day and is carried around by the timekeeper on the job. In the left-hand column he enters the numbers of all the men who are at work, and it will be noticed that the tenth line is a heavy line and that numbers ten, twenty, thirty, and so on appear on these heavy lines always, and if necessary, blanks are left in between to insure this being done.

Job No. 1990 ! — ABERTHAW CONSTRUCTION COMPANY, BOSTON — Date 7/2/13

At Northwood Mass — TIMEKEEPER'S FIELD SHEET — Timekeeper's Name Dunham — Sheet No. 1

Man's Number	In a.m.	In p.m.	Out	7 a.m. to 8	— 9	— 10	— 11	— 12	— 1 p.m.	— 2	— 3	— 4	— 5	— 6	Overtime	Total Hours
Lyell	/	/	/	—	—	—	—	—		—	—	—	—			9
Parker	/	/	/	—	—	—	—	—		—	—	—	—			9
Dunham	/	/	/	—	—	—	—	—		—	—	—	—			9
Rutledge	/	/	/	Fef	Fefb	—	—	—		Mef	—	Fecm	Sev			9
Stevens	/	/	/	Rec	—	—	—	—		Ref	—	—	—			9
611	/	/	/	Fef	—	—	—	Fefm		—	—	—	—			9
614	/	/	/	Fef	Fefb	—	—	—		—	—	—	—			9
616	/	/	/	Fefb	—	—	—	—		—	—	—	—			9
617	/	/	/	Fecm	—	—	—	—		—	—	—	—			9
618	/	/	/	Fefb	—	—	—	—		—	—	Mef	~~Fefb~~			9
619	/	/	/	Fef	—	—	Fec	—		—	—	—	—			9
620	/	/	/	Fef	—	—	Fec	—		—	—	—	—			9
621	/	/	/	Fef	Fefb	—	—	—		—	—	—	—			9
622	/	/	/	Fefb	—	—	—	—		—	—	Mef	~~Fefb~~			9
623	/	/	/	Fefb	—	—	—	Fecm		—	—	—	—			9
639	/	/	/	Fefb	—	Ref	—	Sev		—	—	—	—			9
640	/	/	/	Fefb	Mef	Ref	—	—		Rec	—	Bew	—			9

Fig 7

Job No. 1990 — ABERTHAW CONSTRUCTION COMPANY, BOSTON — Date 7/2/13

At Northwood MASS — TIMEKEEPER'S FIELD SHEET — Timekeeper's Name Dunham — Sheet No 2

Man's Number	In a.m.	In p.m.	Out	7 a.m. to 8	– 9	– 10	– 11	– 12	– 1 p.m.	– 2	– 3	– 4	– 5	– 6	Overtime	Total Hours
651	/	/	/	Mef	—	–	Fir	–		–	Mef	–	–			9
652	/	/	/	Mef	–	Fir	–	–		–	–	–	–			9
653	/	/	/	Mu	–		–				–	–	–			9
654	/	/	/	Mef	–	Fir	–	–			–	–	–			9
655	/	/	/	Rec	.		Ref	–		Rec	.	Ref	–			9
656	/	/	/	Mef	–	Fef	Ref	–		Fef	–	Ref	–			9
657	/	/	/	Fec	.	–	–	–		–	–	–	Fir			9
658	/	/	/	Mef	–	–	Fir	–		Mef	–	–	–			9
659	/	/	/	Mef	–	–	Fir	–		–	Mef	–	–			9
660	/	/	/	Mef	Rec	–	Ref	–		–	Bew	–	–			9
662	/	/	/	Mu	–	.	.	–		–	Fir	.	–			9
663	/	/	/	Rec	–	–	Ref	–		Rec	–	Ref	–			9
664	/	/	/	Fef	–	–	–	–		–	–	–	–			9
665	/	/	/	Mef	–	–	–	–		–	–	–	–			9
667	/	,	,	Mu	–	–	–	–		–	–	–	–			9
668	/	,	/	Bew	–	–	–	–		–	–	–	–			9
670	/	,	/	Rec		–	Ref	–		Rec	–	Ref	–			9
671	/	/	/	Fec	–	–	–	–			–	–	–			9
672	/	/	/	Rec	–	–	Ref	–		Rec	–	Ref	–			9
673	8am	/	/	\	Bew		–	–			–	–	–			8
674	8am	/	/	×	Bew	–	–	–		–	–	–	–			8
675	8am	.	/	×	Bew	–	–	–		–	–	–	–			8
677	/	/	/	Fef	–	–	Ref	.		–	–	Fir	–			9
679	/	/	/	Rec	–	–	Ref	–		Rec	–	Ref	–			9
681	/	/	/	Mu	–	–	–	–		–	–	–	–			9
682	/	×	×	Fef	.	–	Fec	–								5
683	/	/	/	Mef		Fef	–	Fecm		.		–	–			9
684	/	/	/	Fef		–	–	–		–	–	–	–			9
685	/	/	,	Mu	–	–	–	–		–		–	–			9
690	/	/	/	Fef	–	–	–	–		–	Fecm	Fir	–			9
691	/	/	/	Fecm	–	–	–	–		–	–	–	–			9
692	/	/	/	Fef	–	–	Fefb	–		–	–	–	–			9
693	/	/	/	Fecm	–	–	–	–		–	–	–	–			9
697	/	/	/	Fef	Fec	Ref	Peno			–	–	–	–			9
1 Team Murphy				Mu	–	–	–	–		–	–	–	–			9
1 Team Sanders				Mu	–	–	–	–		–	–	–	–			9

Fig 8

(The object of this will be explained later.) After having checked the men in, in the second column from the left, the timekeeper starts on his rounds and in the column headed 7 to 8 he places against each man's number the code word for the work he is doing. On making his second round, which is usually about ten o'clock, if the man is still on the same work he simply

places a check in the intervening columns to show that the same work is going on. The timekeeper has to make at least four rounds every day and has to find each man on every round. If a man is not found, his pay is docked unless he can satisfactorily explain where he was.

It will be noted that the field sheet provides columns for checking the men in after the noon hour and for checking the men out at night and for overtime. The last column is the total number of hours worked during the day, which is used in making up the payroll, as will be shown later.

In going his rounds, the timekeeper carries the field sheet in a stiff binder similar to that used by the express companies. On a large job, sometimes as many as six or eight sheets are used every day. They are of course all numbered up with the numbers of the men before he starts on his rounds. The advantages of this field sheet are as follows:

1. The timekeeper keeps a permanent record of what the men are doing every hour in the day. This is an improvement on the old method, when timekeepers used to take the time on old pieces of scrap paper, backs of envelopes, or pieces of old board, and kept no permanent record of the work in any form. In that way men were frequently missed and their time afterwards guessed at, and there was no check on the men that showed they were all at work.

2. The superintendent can easily check the work of a timekeeper. Most of our superintendents, each time that they go out on to the work, make a note of the numbers of three or four of the men and note what they are doing at that time, and on coming in refer to the timekeeper's field sheet to see what work he has entered them as being on, and by picking out at random a few men every day in this way it is easy to find out whether the timekeeper is doing his work correctly.

3. It is easy to disprove men's claims for more time than they are allowed, as in addition to the record on the payroll we have this actual check on what the men were doing hour by hour, and a man who claims his time is short is confronted with the field sheet, which shows exactly what he has been doing.

4. On a large job, two men can work together on the time-

keeping, for on a job where the payroll is as much as four thousand dollars a week it is all one man can do to go round the work and note the men's time. He turns in his field sheet to an assistant timekeeper, who makes out the payroll and time sheets from it. Under the old methods, when rough notes were made on scrap paper, this would be a very difficult if not an impossible thing to get done correctly, and the result would be that the timekeeper's field work would suffer and the cost accounts would be inaccurate.

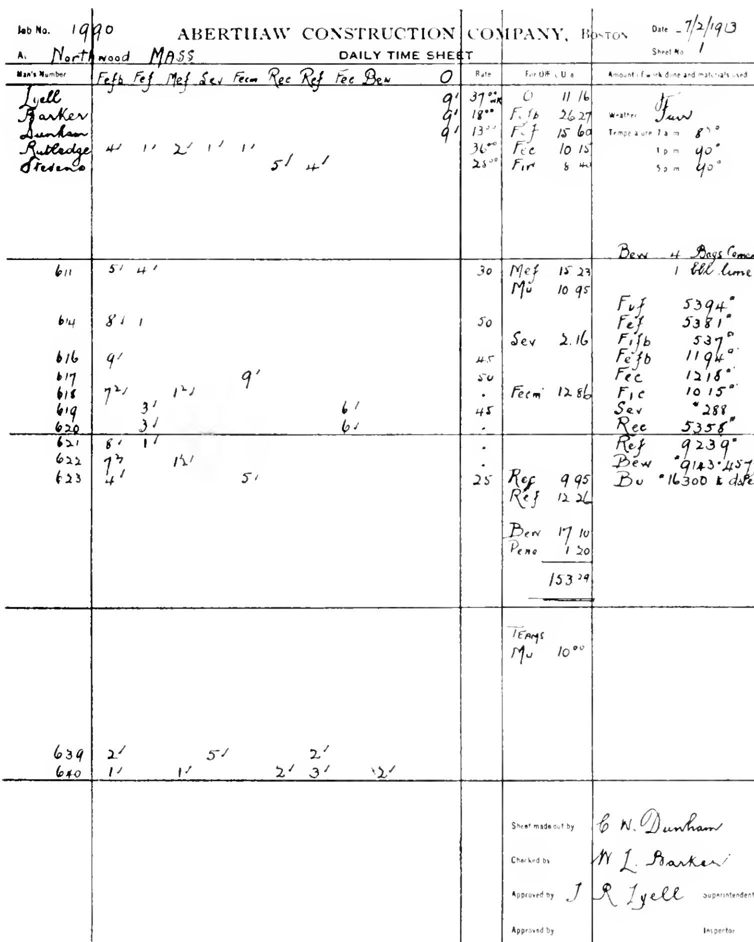
There are necessary limits to the number of subdivisions made in the work. Some timekeepers with more zeal than discretion will multiply subdivisions without end if not watched. It is a standing instruction to our men that the laborer who shakes out and bundles cement bags is to be charged to the largest concrete item of the day, and that the saw filer is to be reported on the largest piece of form work. All time on temporary dams for construction joints in concrete floors are reported with floors. The superintendent, timekeeper and water boy are not so charged but are prorated on every item, as will be seen in section IV–*A*.

B. The Time Sheet.

Figs. 9 and 10 show the daily time sheet. In this it will be noted that the ruling is the same as on the field sheet, with every tenth line reserved for numbers 10, 20, 30, and so on, so that the men's numbers appear always on exactly the same line on each sheet. In the left-hand column are the numbers of the men and on the top of the succeeding column are written the code words of the work in progress. Under these is entered against every man the number of hours he has spent on the section of the work denoted, and on the right-hand side is a column for the man's rate. The next two columns are headed "For Office Use," and when the sheets come into the office the total amount spent on each subdivision of the work is worked up and entered there, as is shown in the example. The extreme right-hand column is reserved for the report of the quantities of the work done, which are entered by the timekeeper every day, or, in

some cases where the work is unfinished at the end of the day, every second or third day.

These sheets are entered up by the timekeeper on the job, sometimes in the evening after the day's work is done, but usually in the morning following the day in which the work was done. They are mailed to the office daily.



Job No. 1990 ABERTHAW CONSTRUCTION COMPANY, BOSTON Date 7/2/1913

At Northwood MASS DAILY TIME SHEET Sheet No. 1

Man's Number	Fefb	Fef	Mef	Sev	Fecm	Rec	Ref	Fec	Bew	O	Rate	For Office Use		Amount of work done and materials used
Lyell										9'	37½	O	11 16	Weather Fair
Barker										9'	18	Fefb	26 27	Temperature 7 a.m. 81°
Dunham										9'	13	Fef	15 60	1 p.m. 90°
Rutledge	4'	1'	2'	1'	1'						36	Fec	10 15	5 p.m. 90°
Stevens						5'	4'				25	Fir	8 40	
														Bew 4 Bags Cement
611	5'	4'									30	Mef	15 23	1 bbl. lime
												Mu	10 95	Fuf 5394
614	8'	1									50			Fef 5381
												Sev	2 16	Fifb 537
616	9'										45			Fefb 1194
617					9'						50			Fec 1218
618	7½		1½								.	Fecm	12 86	Fic 1015
619		3'						6'			45			Sev 288
620		3'						6'			.			Rec 5358
621	8'	1'									.			Ref 9239
622	7½		1½								.			Bew 9143-4574
623	4'				5'						25	Rec	9 95	Bu 16300 to date
												Ref	12 26	
												Bew	17 10	
												Pemo	1 20	
													153 29	
												Teams Mu	10 00	
639	2'			5'			2'							
640	1'		1'			2'	3'		2'					

Sheet made out by C. N. Dunham

Checked by W. L. Barker

Approved by J. R. Lyell Superintendent

Approved by Inspector

Fig 9

Job No. 1990 ABERTHAW CONSTRUCTION COMPANY, BOSTON Date 7/2/13

At Northwood, Mass DAILY TIME SHEET Sheet No. 2

Man's Number	Mef	Fir	Mu	Rec	Ref	Fef	Fee	Bew	Fem	Fefb	Perr	Rate	For Office Use
651	6'	3'										50	
652	2'	7'										25	
653			9'									"	
654	2'	7'										"	
655				5'	4'								
656	2'				4'	3'						35	
657		1'					8'					25	
658	7'	2'										"	
659	6'	3'										27½	
660	1'			2'	3'			3'				45	
662		3'	6'									25	
663				5'	4'							30	
664						9'						25	
665	9'											35	
667			9'									25	
668								9'				"	
670				5'	4'							"	
671							9'					"	
672				5'	4'								
673								8'				62½	
674								8'				37½	
675								8'				62½	
677		2'			4'	3'						27½	
679				5'	4'							25	
681			9'									30	
682						3'	2'					25	
683	2'					7'						"	
684						4'			5'			"	
685			9'									"	
690		2'				6'			1'			25	
691									9'			"	
692						3'				6'		"	
693									9'			30	Sheet made out by C W Dunham
													Checked by H L Barker
697					1'	1'	1'				6'	20	Approved by J R Lyell Superintendent
1 Teams			9'									5.00 day	
1 Teams			9'									5.00 day	Approved by Inspector

Amount of work done and materials used

Weather

Temperature, 7 a.m.

1 p.m.

5 p.m.

Mef. Concrete stops, hoisting runways, barrows etc to roof

Fig 10.

C. *The Payroll.*

Figs. 11 and 12 show the payroll, which is also ruled up in sets of ten lines, like the field sheet and the time sheet. This is similar to all contractors' payrolls and needs no comment, except to point out the immense saving of time that has been made by the use of time sheets, field sheets and payrolls, all

ruled uniformly, and insisting on leaving blank spaces rather than using every line on the time sheets and payroll. The payroll is filled in simply by placing the field sheet over the payroll, and transferring the number of hours' work without even referring to the men's number. The payroll is then checked by the time sheet, so that there is a circular check on the whole of the operation.

Job No. 1990 ABERTHAW CONSTRUCTION COMPANY, BOSTON Page 1
at Northwood Mass PAY ROLL From 6/26/1913 to 7/2/1913

Men's No	26	27	28	29	30	1	2	Total Hours	Rate	Amount
Lyell	9	9	9		9	9	9	54	37 00	37 00
Barker	11	9	9		10	9½	9	57½	18 00	18 00
Dunham	11	9	9		10	10	9	58	13 00	13 00
Rutledge	9	9	9		10	10	9	56	36 00	36 00
Stevens	9	9	9		9	10	9	55	25 00	25 00
611	9	9	9		10	10	9	56	30	16 80
614	9½	9	9		10	10	9	56½	50	28 25
615	5							5	30	1 50
616	9	9	9		8	10	9	54	45	24 30
617	9	9	9		10	10	9	56	50	28 00
618	9	9	9		10	10	9	56	"	28 00
619	9½	9	9		10	11½	9	58	45	26 10
620	9	9	9		9½	11½	9	57	"	25 65
621	9	9	9		10	10	9	56	"	25 20
622	9	9	9		10	10	9	56	"	25 20
623	10	9	9		10	10	9	57	25	14 25
639	11	9	5		10	9	9	53	30	15 90
640	11½	9	9½		10	10	9	60	25	15 00

Sheet made out by C. W. Dunham Approved J. R. Lyell Supt. Total $
Checked by W. L. Barker Approved .... Inspector

Fig. 11.

Job No. 1990	ABERTHAW CONSTRUCTION COMPANY, BOSTON									Page. 2
at	Northwood Mass				PAY ROLL			From	6/26/13	to 7/2/13
Man's No.	26	27	28	29	30	1	2	Total Hours	Rate	Amount
651	12½	9	9		10	9	9	64½	50	32 25
652	11½	1	9		9½	5½	9	45½	25	11 38
653	11	9	9		9	9	9	56		14 00
654	11	9	5		9½	9	9	52½	.	13 . 13
655	11	9	9		10	10	9	58		14 50
656	12	9	9	6	9½	9	9	63½	35	22 23
657	12½	9	9		9½	9	9	58	25	14 . 50
658	12½	9	9	6	9½	10	9	65		16 25
659	12	9	9		9½	9	9	57½	27½	15 81
660	12½	9	9		10	10	9	59½	45	26 78
662	12	9	9		4	6½	9	49½	25	12 38
663	11	9	9		10	10	9	58	30	17 40
664	11½	9	9		10	9	9	57½	25	14 38
665	12	9	9	6	9½	9	9	63½	35	22 23
666	6½							6½	25	1 63
667	11	9	9		9	9	9	56	.	14 00
668	11½	9	9		9	9	9	56½	.	14 13
670	11½	9	9		9½	10	9	58	25	14 50
671	11	9	9		10	10	9	58		14 50
672	11	9	9		9	10	9	57	.	14 25
673	8	8	8		8	8	8	48	62½	30 00
674	8	8	8		8	8	8	48	37½	18 00
675		8	8		8	8	8	40	62½	25 00
677	11½	9	9	6	9½	9	9	63	27½	17 33
679	11½	9	5		9½	10	9	54	25	13 50
681	11½	9	9		9	9	9	56½	30	16 95
682	11	9	9		9½	9	5	52½	25	13 13
683	11	9	9		10	10	9	58	.	14 50
684	2	9	9		5	2	9	36	.	9 00
685	11½	1	9		9	9	9	48½	.	12 13
686		9	9		10	5½		39½	.	8 38
690	11	9	9	6	9½	9½	9	63	25	15 75
691	12	9	9		10	10	9	59	.	14 75
692	11½	9	9		10	10	9	58½	25	14 63
693	11	9	9		10	10	9	58	30	17 40
697	11½	9½	8		10	10	9	58	20	11 60
										572 28
									Total first sheet	402 . 15
Sheet made out by	C. W. Dunham	Approved	Y. A. Lyell		Supt.			Grand	Total	$974 43
Checked by	N. L. Parker	Approved	Fill 12		Inspector					

D. The Quantity Report.

This has already been referred to when considering the time sheet. It is of course of vital importance that the quantities should be accurately reported. We make it the duty of the engineer in charge of the level and transit to compute the quantity of work done each day and turn it in to the timekeeper to

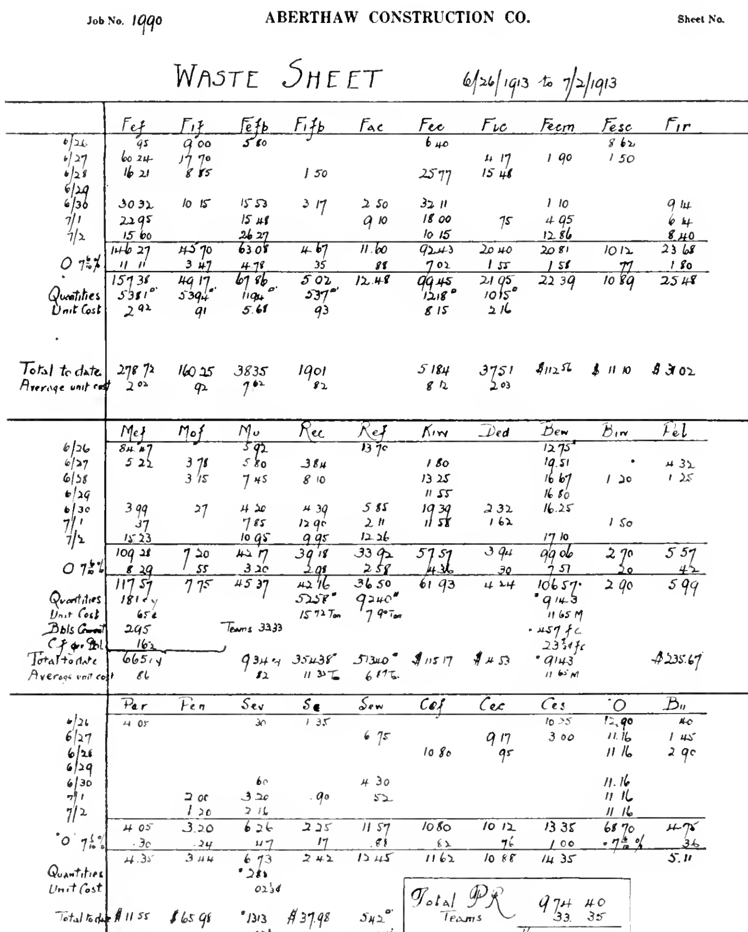
enter in the column provided. It is often a difficult matter to insure correct reports being received on the quantities of work done, and at the time the system was installed the writer made a practice of visiting jobs monthly and making a rough survey of them whereby he could calculate from his original estimate the quantity of work done, and using this as a check. The practice on our work has improved a good deal since then and it is very seldom necessary now to make this check, but it is one that should not be neglected by any one starting on a cost accounting system, as without this check the cost accounts may be rendered worthless by quantities either in excess or less than the actual amounts being reported. On one job, some years back, we found that a superintendent had reported 20 000 sq. ft. more forms than he had put up, with a view to making his costs look low and getting credit for economical work. Our estimates show what the total quantities should be, and an occasional survey and a final comparison will prevent any such errors being made now.

In concrete work the only item of labor that can be checked from the bills is the steel reinforcement, and every other quantity has to be obtained by scaling and computation. This is also true in most other branches of construction work, with the exception of structural steel.

E. The Inquiry Form.

We also use a brief standard form in case of any apparent mistakes on any of the reports received from the field. Often a man's rate is entered wrongly, or a different number of hours appears on the payroll to that on the time sheet, or time is reported with no quantities or quantities with no time. It is only by picking up all these mistakes at once and having them corrected that a system is kept going properly, and the men in the field, knowing that their work is carefully watched, are more keen in getting work done accurately. This may seem to be a trivial detail but the writer's experience is that it is not possible to get accurate and careful work from men in the field unless careful attention is paid to the smallest items, and any

inaccuracies or omissions are promptly followed up. If the men on the job are made to realize that their work is important and really counts for something they will be a good deal more careful and eager to coöperate with the office in matters like this.



Job No. 1990 ABERTHAW CONSTRUCTION CO. Sheet No.

WASTE SHEET 6/26/1913 to 7/2/1913

	Fef	Fif	Fefb	Fifb	Fac	Fec	Fic	Fecm	Fesc	Fir
6/26	95	9 00	5 60			6 40			8 62	
6/27	60 24	17 70					4 17	1 90	1 50	
6/28	16 21	8 85		1 50		25 77	15 48			
6/29										
6/30	30 32	10 15	15 53	3 17	2 50	32 11		1 10		9 14
7/1	22 95		15 48		9 10	18 00	75	4 95		6 14
7/2	15 60		26 27			10 15		12 86		8 40
	146 27	45 70	63 08	4 67	11.60	92 43	20 40	20 81	10 12	23 68
O 7 6/10 %	11 11	3 47	4 78	35	88	7 02	1 55	1 58	77	1 80
	157 38	49 17	67 86	5 02	12.48	99 45	21 95	22 39	10 89	25 48
Quantities	5381°	5394°	1194°	537°		1218°	1015°			
Unit Cost	2 92	91	5.68	93		8 15	2 16			
Total to date	278 72	160 25	3835	1901		5184	3751	$112 56	$ 11 10	$ 31 02
Average unit cost	2 02	92	7 62	82		8 12	2 03			

	Mef	Mof	Mu	Rec	Ref	Kiw	Ded	Bew	Biw	Fel
6/26	84 47		5 92		13 70			12 75		
6/27	5 22	3 78	5 80	3 84		1 80		19.51		4 32
6/28		3 15	7 45	8 10		13 25		16 67	1 20	1 25
6/29						11 55		16 80		
6/30	3 99	27	4 20	4 39	5 85	19 39	2 32	16.25		
7/1	37		7 85	12 90	2 11	11 58	1 62		1 50	
7/2	15 23		10 95	9 95	12 26			17 10		
	109 28	7 20	42 17	39 18	33 92	57 57	3 94	99 06	2 70	5 57
O 7 6/10 %	8 29	55	3 20	2 98	2 58	4 36	30	7 51	20	42
	117 57	7 75	45 37	42 16	36 50	61 93	4 24	106 57	2 90	5 99
Quantities	181 cy			5258°	9240°			9143		
Unit Cost	65¢			15 72 Ton	7 90 Ton			11 65 M		
Bbls Cement	295		Teams 3333					457 fc		
Cf per Bbl	162							23 3/4 fc		
Total to date	665 cy		934 cy	35438°	51340°	$115 17	$ 4 53	9143		$235.67
Average unit cost	86		82	11 30 T	6 11 T			11 65 M		

	Par	Pen	Sev	Se	Sew	Cef	Cec	Ces	O	Bu
6/26	4 05		30	1 35				10 35	12.90	40
6/27					6 75		9 17	3 00	11.16	1 45
6/28						10 80	95		11 16	2 90
6/29										
6/30			60		4 30				11.16	
7/1		2 00	3 20	.90	52				11 16	
7/2		1 20	2 16						11 16	
	4 05	3.20	6 26	2 25	11 57	10 80	10 12	13 35	68 70	4 75
O 7 6/10 %	.30	.24	47	17	.88	82	76	1 00	7 6/10 %	36
	4.35	3 44	6 73	2 42	12 45	11 62	10 88	14 35		5.11
Quantities			288							
Unit Cost			02 3/4							
Total to date	$11 55	$65 98	1313	$37.98	542°					
			.03½		04⅓					

Total PR	974 40
Teams	33 35
	$1007 75

FIG. 13

Section IV.

THE WORK IN THE OFFICE — LABOR RECORDS.

A. Working up the Time Sheet.

As soon as the time sheets come into the office, the total cost of each operation is worked out and entered in the column headed " For Office Use " on the time sheets, as shown in Fig. 9. At the end of the week the totals are drawn off on to an abstract sheet, shown in Fig. 13, and the items are totaled. The overhead labor expense (superintendent, timekeeper, waterboy, etc.) is then distributed by adding a percentage to each item, and the complete cost of each operation for the week is arrived at. The quantities are then written underneath each one and the unit costs worked out. They are then entered on the office record sheets, which will be described in the next section, and under them is entered the total quantity of work done to date (which is obtained from the office sheet) and the average cost of the work to date.

B. The Weekly Summary.

Fig. 14 shows a copy of the weekly summary of labor costs. The top line shows the total amount spent during the week on the items. The second line shows the quantity done, and the third line the unit cost. There are then left two or three lines for notes; in the case of concrete the number of barrels of cement used and the number of cubic feet of concrete obtained with a barrel of cement is noted. The two lower lines show the total quantity of that kind of work done to date and the average cost. Four copies of this sheet are made every week, and are furnished to the heads of the firm and the general superintendent, and one copy goes to the superintendent in the field. He also has a copy of the analysis. With these two he is able for himself to see how the costs of his work are running and how they compare with the estimate. Most of our superintendents also work out daily unit costs in the field on the larger items of the work, to keep more closely in touch with their costs. We believe in letting our men know just what we expect of them in the way

of costs and letting them know just how they are coming up to or bettering our expectations. Since we adopted the plan of letting them know what the weekly costs were, there has been a marked improvement in the unit costs and a real enthusiasm for getting low costs.

I may be asked why we do not " go one better " and work out daily costs in the office instead of weekly. The reason this

ABERTHAW CONSTRUCTION CO. BOSTON
WEEKLY SUMMARY

Job No. 1990 **At** Northwood Mass **Week ending** July 2^{nd} 1913

Item	Fef	Fif	Fefb	Fifb	Fac	Fec	Fic	Fecm	Fesc	Fir		Mef	Mof	Mu		Rec	Ref		Kiw		Ded		Bew	Biw	Bu
Total cost	157^{78}	44^{17}	67^{86}	5.02	12^{48}	99^{45}	21^{95}	22^{39}	10^{89}	25^{48}		117^{57}	7^{75}	45^{37}		42^{16}	36^{50}		61^{93}		4^{24}		106^{57}	2^{90}	5^{11}
Amount done	5381	5394	1194	537		1218	1015					181 cy				5255	9240						9143		
Unit cost	2^{92} sq	91	5^{68}	93		8^{15}	2^{16}					65		Teams		15^{72} Ton	7^{90} Ton						11^{65} M		
											CF Bbls	295		33^{33}									457½		
												16½											23½¢		
Total Done	27872	16025	3835	1901		5184	3751	$\$112^{56}$	$\$11^{10}$	$\$31^{02}$		665 cy		934 cy		35438	51340		$\$115^{17}$		$\$4^{53}$		9143		
Average Cost	2^{02} sq	.92 sq	7^{62} sq	83 sq		8.12 sq	2^{03} sq					86		82		11.32 Ton	6^{87} Ton						11^{65} M		
Item	Pel	Per	Pen		Sev	Se	Sew		Cef	Cec	Ces		O												
Total cost	5^{99}	4^{35}	3^{44}		6^{73}	2^{42}	12^{45}		11^{63}	11.88	14^{35}		68^{70}												
Amount done					288								$7\frac{6}{10}$												
Unit cost					.023¢																				
																Payroll			$	974	40				
Total Done	$\$235^{67}$	$\$11^{55}$	$\$65^{96}$		1313	$\$37^{96}$	542						Included in preceding amounts			Teams				33	35				
Average Cost					.03½		.04½																		

FIG. 14

is not done is not on the ground of expense — although it would be a very expensive proceeding — but because if we worked out the cost of every item every day we should have such an overwhelming mass of figures to study that we should never have any clear idea as to how the jobs stood, — and then again the costs would show such astonishing variations from day to day that they would be in many cases useless. For example, suppose a line of sheet piling set up and braced one night but not driven right down till next day, following our rule (to report quantity when work is done) one day would show a large expense in money and no quantity, the next a large quantity with small expense and exceedingly low unit cost.

Job No. 1990 **ABERTHAW CONSTRUCTION CO.** Sheet No. 2

MED Concrete footings

	Quantity	Unit cost	Total $	Average	Bbls Ct	c f bbl
5/14	4 cy	2.94	11.78		5	21½
5/21	121	.82	98.83	.88½	16.7½	19½
5/28	130	1.33	172.50	1"	15.2	33
6/4	9	1.96	9.67	1"	10½	22½
6/25		Mod	8.00	1.14		
Total.	264	1"	300.78		3.35	

MEF—Concrete floors & columns

	Quantity	Unit cost	Total $	Average	Bbls ct	Cf bbl
5/28			2.79			
6/4	70½	75½	53.19	.79½	115½	16½
6/11	110	75	82.62	.76¾	198	15
		Mof	16.91	86		
6/18	138	1.03	141.73		244½	15¼
		Mof	4.10	95		
6/25	166	68	112.52			17½
		Mof	46.90	95	31	
7/2	181	65	117.57		295	16½
		Mof	7.75	86		
7/9	147½	64	95.49		228	17
		Mof	29.68	84	11	
7/16	11	2.18	24.03		20	15
		Mof	41.00	94	10	
7/26	"	Mof	56.37	1.01	3	
	824	1.01	833.15		1410	

MEWS Concrete window Sills

	Quantity	Unit Cost	Total $	Average	Bbls Ct.
6/25	122	.15	18.30		9¼
7/9	238	.14½	34.33	14%	9
7/16	117	.20	23.57	19	6¼
		Mows	15.90		
7/16	157	.14	22.51	18	7¼
Total	634	18	114.51		32 bbls

MECC Cinder Concrete (Screeds separately)

	Quantity	Unit Cost	Total $	Average	Bbls Ct	Cf bbl
7/9	23 ½ cy	2.27	52.89		40½	15½
7/16	72	1.93	139.40	2.02	100	19
	Crickets		8.70		5	
7/26	32	1.92	61.38	2.06	49	27
Totals	127	2.06	262.37		194½	

KIW Rub with carborundum

	Quantity	Unit cost	Total $	Average
6/18			6.00	
6/25			47.24	
7/2			61.93	
7/9			38.48	
7/16			64.29	
7/26			93.30	
			311.24	

MUCC Loading & teaming cinders

	Quantity	Unit Cost	Total $	Average
7/9			59.64	
			16"	
7/16			43.25	
			119.05	

FIG. 15

C. *The Office Labor Sheets.*

Fig. 15 shows the regular record kept in the office of the labor. This sheet shows only a few items and there would be some ten or twelve sheets for every job. It will be seen that the first column contains the date, next the quantity of work done in the week, the next the unit cost of that work, and the next column

the total cost of that work. The next column contains the average cost of the work to date, combining the week's work with all the previous weeks. In the case of concrete, two additional columns are used, giving cement used and the proportion of the mix. These are entered up from week to week from the abstract mentioned previously. The totals are kept in pencil at the foot of the columns and altered from week to week, so that it is a simple matter to add one week's work to the total of the preceding week and work out the average unit cost.

On some items, such as forms, the cost of making, erecting and stripping of forms is carried in separate columns, and another column is kept for the total unit cost of the work to date. This is obtained by adding the totals of the three money columns and dividing by the number of square feet erected. This inclusive unit cost does not give quite such an accurate idea of the cost as the three subdivisions do, as all the making is done at the beginning of the job and some of the stripping may not come until a good while after, but is in many cases a very useful figure to have, and it is, of course, the figure which compares with the analysis which is made out at the beginning of the job. As already mentioned, when the cost of the item for the week has been entered, the average is worked out and then the resulting average and the total quantity to date is transferred back to the waste sheet from which the weekly summary is made out.

Section V.

IN THE OFFICE. THE MATERIAL RECORDS.

Figs. 16 and 17 show a part of the material records kept in the head office. These are entirely distinct from the bookkeepers' records and are not a ledger account. No merchants' names appear as a rule, but chiefly quantities of materials and costs.

The records are kept on loose sheets and at the start of the job columns are headed for each item that appears in the analysis. In some cases these items are subdivided. Then every item of expense is entered under its proper heading regularly as the work goes on. Freight in every case is entered with the item to which it relates. Demúrrage also is entered in the columns

of "Cement," "Brick," "Lumber," etc., as the case may be. The column headed "Cement" will also contain items of freight, freight on empty bags, credit on empty bags, tests, demurrage, etc., so that the final price per barrel of cement that appears in the final summary may be several cents higher than the price entered on the original order, especially if many empty

Job No. 1990 **ABERTHAW CONSTRUCTION CO** Sheet No. 1

MATERIAL RECORDS

PLANT

SMALL TOOLS SUPPLIES

J 22	Lights Shovels pick handle	12 02
.	Bolts & Washers Clips ...	21 50
.	Misc small tools & supplies	35 33
.	Oil clothing 54 68 Lights 3 55	58 73
.	Sharp Tools	3 40
. 30	3 pieces iron 2 45 Yard labor & team	23 00
. 68	Credit Switches etc to yard	12 60 x
.. 45	Switches fuses etc	14 50
.	Repair gears	25 23
	Small tools	14 10
	Wire ropes	8 28
	Power	24 60
	Sharp tools 2 40 Parts rope etc	23 25
	Power	63 20
		314 90

RENTAL

J 08	for entire job	513.40

OFFICE TRAVEL BOARD &c

J 15	Fares telegrams, misc exps	69.00
J 22	Tel 11 83 Stationary 5 54	17 37
	Teleg	98
J 30	Express on money	8 05
[68	Tel fares etc	8 55
	Travel from Office	143 03
J 45	Tel	28 00
J 62	Express 4 00 Chair & desk	25 18
..	Tolls 10 39 Telegram 78	11 17
.	Tel	2 14
J 08	Credit Desk	15 00 x
		295 37

FREIGHT TEAMING

J 15	Yard labor 6 96 T. 19 50	26 46
.	Misc expressage plant	24 52
J 62	Frt C. O.	60 70
		111 70

TEMP BUILDINGS.

J 38	Lumber for misc plant	331.68
.	Roofing paper	12 25
18	Credit sold shanty	58 75 x
		285 18

Form Details from Boston Office

J 15	Blue prints & tel.	12 16
	Draftsman's time	68 24
		80 40

RENT of LAND for working space

J 62	Monstruck Silk Co	35 00

WATER SUPPLY

J 52	North Water Works	10 60
.	Misc fittings	17 39
. 68	Water	8 33
		36 52

FIG. 16

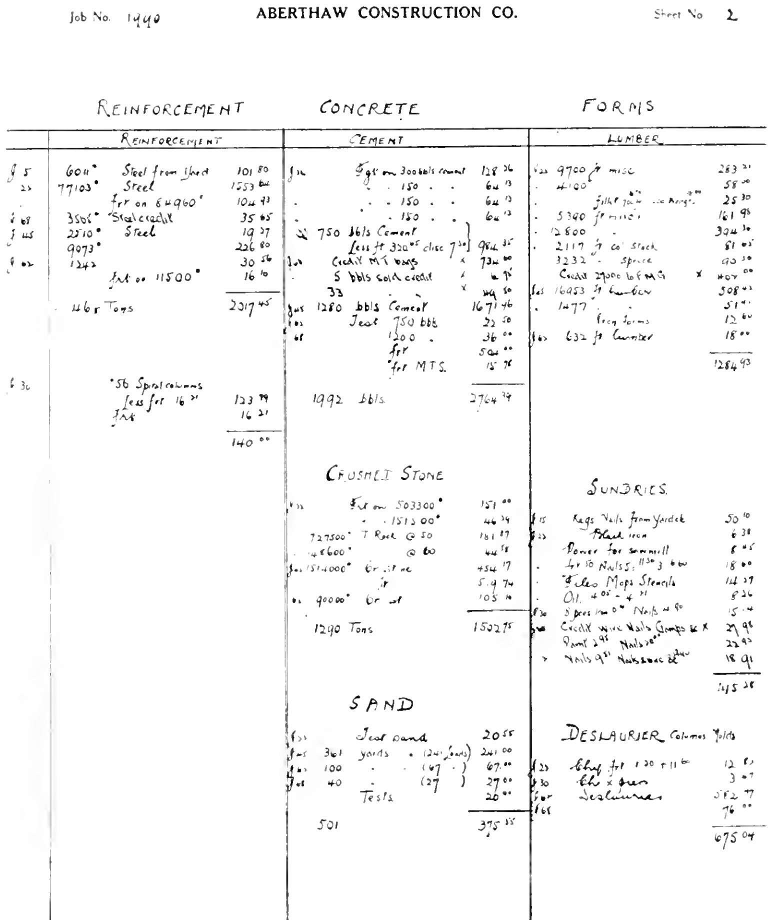


FIG. 17

bags have been lost. There is no column for all lumber. Lumber is entered under "Plant," "Forms," "Roof Plank," "Cofferdams," "Temporary Buildings," etc., according to the use it is to be put to. If lumber is bought for sheeting trenches and afterwards used for forms, it is first entered to the excavation item and then its second-hand value is credited and charged to

forms. Credits are entered in red in the same columns as debits, as there are very few of them and it would be cumbersome to have to keep double columns for each item to provide for possible credits.

To get hold of the information entered in these sheets the procedure is as follows: All bills are sent to the job to be checked and returned to the head office, from whence they are paid. As soon as the receipted bills come in they are sent to the Cost Accounting Department. They are then entered up in a waste book and at once returned to the bookkeepers. One waste book only is kept, and the bills are entered as they come in, a page at a time being kept for each job number, and another page taken when one is filled. When the bills are checked at the job, the material clerk notes on same what the material was used for (as in the case of lumber just referred to). This information is usually put in by using the timekeeper's code and then there is no question in the Cost Accounting Department as to where to charge any unusual item. The use of the waste book is simply to save time. The weekly labor summaries take precedence in the Cost Accounting Room, and on the last three days of the week we are much too busy getting these out to give any time to the material sheets. These can be entered up later in spare moments. Once a month, at least, each job is brought up to date and the total compared with the bookkeeper's ledger.

All orders are also examined by the Cost Accounting Department, and a note sheet kept on each job of all large orders and subcontracts, so that when a monthly statement is made of the financial standing of the job these can be included. The saving or loss on the estimate when a contract such as painting is sublet is not made when the final payment has been made but when the order is given, and should be taken into account then. We do not, however, keep a record of any but the big orders, as the thousand and one small items of nails, bolts, tools, etc., are billed and paid for very soon after receipt and quickly find their place in our records from the bills.

Section VI.

THE MONTHLY STATEMENT.

Fig. 18 shows the statement which is prepared monthly to ascertain the amount of money saved or dropped on the job. These are not made for every job on the same day, but by taking two or three jobs in turn each week we make it part of our regular routine without undue pressure at any time.

The weekly summaries showed labor costs only. If any item (excavating, for instance) was costing 20 cents per yard more than the estimate, it did not show how many dollars the total loss amounted to. Every job fluctuates from week to week. Some items are over the estimate and some show a saving. This statement brings these items all into view in such a way as to show how serious an over run may be, and the final footings show within a very small amount just how the job stands.

The way the sheet is made up is, — first to copy from the analysis the description of all the items and place the unit prices in the column provided on the left. Then from the labor and material records to enter in the "Actual Cost" columns quantities of work done and materials purchased, with their unit costs and total costs to date. Then to work out in the "Estimated Cost" column the cost of the quantities done at the estimated prices. Then to enter all subcontracts made in the "Actual Cost" column and the corresponding "Estimated Cost," and finally to work out the totals saved or lost on each group of items.

A glance at the sheet before us will show some considerable variations from the original estimate. It is not within the scope of this paper to discuss the actual costs on this work, but it will be well to point out what is shown on the sheet and to give a few explanations as to local conditions to make things clear.

It will be seen, first, that concrete labor is running very close to the estimate, although the quantity placed in the footings was eighteen yards in excess of that estimated. Plant shows a loss of $268, chiefly on the labor items. An old construction elevator was sent to the job, which was rather out of repair and several parts had to be refitted or remade before it could be

erected. There is also a loss on the sand and stone. It was found that the crusher that had been counted on to supply us could not be depended on and so we had to purchase from a quarry further off, having a railroad delivery, and to unload and team from the railroad, about a mile to the site. As we were thus using teams regularly, we decided to buy sand F.O.B.

Job No. 1990 ABERTHAW CONSTRUCTION CO. Sheet No

Monthly Statement of Costs to & including June 23rd 1913

		Estimated Cost		Actual Cost		Saving	Loss
Concrete footings labour	246 c.y.	1.00	246	264 c.y.	293		
floors	248 c.y.	1.00	248			4	
Columns	70	1.50	105	.75	302		
Plant erect & repair			250		440		
freight		half	75		100		268
rental & depreciation			300		300		
Small tools & supplies etc			450		503		
Cement	1525 bbls	1.35	2464	1.35	2464		
" tests		.03	55	.03	55		
" teaming etc			91		91		
Sand for whole job	520 c.y.	.80	416	.67	347		
Crushed stone	1400 tons	1.40	1960	1.28	1792		264
Teaming sand and crushed stone to date					506		
Forms to footings labour	4580 □'	7.00	321	2375 sq. ft 10.84	257		
floor slabs	16000 □'	7.00	1120	3.48	557		
wall beams	950 □'	9.00	176	8.40	174		
external columns	2733 □'	11.00	301	11.51	314	642	
" wall brackets			30	incl.			
internal columns sublet			771		675		
A.C.C. labour in connection					100		
Form lumber nail oil etc			1070		1747		
Sawmill labour & equipment			200	not used			
unloading & hauling lumber			50		41		168
probable credit on lumber at close			300				
Steel Reinforcement	46 Tons	37.00	1702		2064		
Spirals	2½	60.00	150				212
Labour ~~unloading~~ & teaming			24		82		
" bending & placing slabs	15	8.00	120	6.79	102		
" " beams	3⅓	8.00	27	4.26	14		153
" " Columns	10	8.00	80	11.90	119		
Wire & sundries			24		6		
Excavation	100 c.y.	.50	50	438 c.y.			
	553	.80	443	1.70	745		
Sheet Piling labour			150		138		45
lumber			350		208		
Miscellaneous C.I. work			400				
W.I.			271		428	294	
Riveted bearing plates in footings			51				
Inserts	100	.10	90	.11	99		
" labour	504	.05	26	.05	26		9
Steel Sash & glazing			2270	sublet	2270		
Travel & board etc. to date	half		150		92	58	
Insurance	day		350		401		51
				Totals		998	1228
		Net overrun on Estimate to date				$230	

FIG. 18

teams at the pit, instead of F.O.B. the job, so as to keep teams steadily employed, so the statement shows a saving on sand and stone offset by an overrun on teaming. It is not necessary at this time to discuss the other variations but simply to note that the difference between the savings and the losses shows a net loss of $230 on the estimated total.

The amount of contractor's profit does not appear on these sheets or in any of the Cost Accounting records, and the amounts of saving or loss in the monthly statement have to be added to or deducted from the estimated profit.

Section VII.

MONTHLY COMPARISON OF BEST PERFORMANCES.

Fig. 19 shows a statement we prepare monthly showing the unit labor costs of the three or four principal items of construction on all jobs during the preceding month. A copy of this sheet is sent to every one of our foremen and superintendents. This is not an essential part of our system but it is awaited with great interest by our field superintendents and has proved a very useful factor in stimulating a general interest in the timekeeping and cost accounting work, and is an additional incentive to our men to try for low costs.

The costs shown on this statement are nearly always lower than our average costs, as they show the best work done month by month and do not bear any preliminary expense or other incidental items. They will give some idea of what *can* be done under favorable circumstances but would not be a safe guide for estimating future work.

Section VIII.

THE FINAL COMPARISON.

Figs. 20 and 21 show the final comparison of estimated with actual costs. This is similar to the monthly statement (Section VI) and needs no further explanation as to the method adopted, but a brief notice of some of its chief features will be of interest.

ABERTHAW CONSTRUCTION COMPANY.

Principal Unit Costs for Month of October, 1911.

	Job No.	Cu. Yds.	Unit Cost.
Concrete — Unload, mix and place.			
N.B. 2 mixers on Job 941.			
Largest 6 days' run of concrete,	917	313	$0.71
	941	2 205	.38½
	944	602	.62½
	946	558	.57
Largest 1 day run of concrete,	917	107½	.80½
	941	451	.38
	944	150	.54½
	946	233	.51½
Lowest day's unit cost — floors,	917	96	.68½
	941	408	.31⅓
	944	16½	.31½
	946	132	.38
Month's average unit cost,	917	700	1.17
	941	5 030	.59½
	944	1 418	1.02
	946	393	.84
		Sq. Ft.	Per 100 Sq. Ft.
Forms — Erecting only.			
Floor forms,	917	45 628	$3.53
	941	291 016	3.92
	944	82 107	6.24
	946	24 568	7.10
Wall forms,	917	None	None
	941	31 556	5.80
	944	3 855	9.59
	946	15 247	7.47
Column forms,	917	3 725	3.17
	941	41 260	7.15
	944	11 494	9.08
	946	7 095	10.05
		Tons.	Per Ton.
Placing Floor Steel (beam and slab),	917	82.18	$5.36
	941	886.5	4.17
	944	63.82	6.47
	946	37.00	6.85
Bend and Place Column Steel,	917	6.56	5.30
	941	14.33	2.84
	944	15.92	8.62
	946	7.33	14.71

FIG. 19.

The cost of laying wood screeds to receive top flooring was unexpectedly high. The bulk of it was done in one week at the close of the job when the best of the men had been transferred elsewhere, and is a good illustration of the necessity of unceasing vigilance in superintendence to avoid sudden drops like this. The rest of the carpenter work was very well done, showing a saving of $944 on the forms. Plant continued to run high;

Job No. 1990 **ABERTHAW CONSTRUCTION CO.** Sheet No. 1

Final Statement of Costs.

	Quantities Estimated	Quantities Reported	Estimated Cost		Actual Cost		Saving	Loss
Concrete Labour in footings	246 cy	264 cy	1.00	246	1.14	301		
" " columns	169 "	169 "	1.50	254	1.01	171		
" " floors	690 "	655	1.00	690	1.01	662	37	
" " window sills	629 fl	634 fl	15	95	18	114		
" cinder concrete crickets				20				
" cinder concrete fill					2.06	262		
& laying screeds	125 cy	127	2.00	250	Screeds	326		338
Rub with carborundum				300		311		11
Plant Labor erect & dismantle				300		801		
" freight etc				150		112		
" rental				300		514		864
" Small tools & supplies				450		637		
Cement	2000 bbls	1972 bbls	1.35	2700	1.36	2682		
" tests			03	60	03	59		
" unloading teaming &c				100.		92		
Sand	520 cy	501	80	416	.75½	376		106
Crushed Stone	1400 tons	1290 tons	1.40	1960	1.16	1502		
Teaming sand & stone						546		
Cinders	130 cy		50	65	Labour 119 Mtl 3	202		
Concrete sundries				52				
Forms to footings labour	Sq ft 4580	2375	7.00	321	10.8	257		
" floor slabs	28618	27872	7.00	2005	3.58	997		
" wall beams	3918	4025	9.00	359	9.34	376		
" external columns	7300	6808	11.00	803	9.03	615		
" wall brackets	55		70	39	Incl.			
" internal col. heads	Sub contract			771	Sublet Acc.	675 115	944	
" window sills	629 fl	631	15	94	16	101		
Form lumber, nails, oil etc				1070		1430		
Unloading & handling lbr, cleaning "				50		221		
Sawmill				200	Not used			
Detailing forms in Boston Office				100		81		
Steel Reinforcement	46 T	46⅓ T	37.00	1702	av 43.66	2017		
" " spirals	2½ T	2½ T	60.00	150	56.00	140		
" " tests				10				
" " unloading	48½ T		50	24				311
" " wire & sundries				24				
" " bend & place in floors		26½ T	8.00		8.14	217		
" " " " " columns	48½ T	17 T	8.00	388	11.32	193		
" " " " " Sundries		5½ T	8.00		7.00	36		
Inserts	1000	1313	.10	100	09½	128		
" labour	1000	1313	.05	50	.03½	46	23	
" billed as extra	313		15	47				
Carried forward							1004	1630

FIG. 20

Job No. 1990 **ABERTHAW CONSTRUCTION CO.** Sheet No. 2

	Quantities	Estimated Cost		Actual Cost.		Saving	Loss
Brot. forward.						1004	1630
Brickwork labour	1200 c.f.	20	240	27½	332		
material	28 M		420	9.00	256		
				Lime	42	8	
				Cement 17bbls	23		
Cutting & patching old work			50		49		
Metal lathed & plastered partition			54		37	17	
Repair old floors			250		172		
Pine Posts			160		115	128	
Wood Stairs			35		30		
Pipe Rail			50				
Miscellaneous cast iron work mall			400				
wrot			271		428	376	
Rivetted bearing plates			51				
Labour on Misc ironwork			106		74		
Tinned doors			60	inc frames	91		31
Steel Sash & glazing			2270		2270		
erection	5262 sq ft	05	263	05½	268		5
Excavation	100 c.y.	Estd 50	50				
	553 c.y.	80	442				
Reported	438 c.y.			1 70	745		86
Grading			100		10		
Sheet Piling lumber			350		218		
labour			150		205		
Clean up the job, clean glass etc			100		124		24
Travel, board, superintendence etc			300		295	5	
Liability Insurance			400		450		50
Contingencies & sundries.			400		55	345	
						1883	1826
		Net gain in Estimate.				$57	

FIG. 21

110 tons less stone was used than estimated, owing to its being extremely well graded and therefore economical in use. Cinders cost three times the estimated amount, owing to there being none available at the owner's plant and no other factories near that could supply us. Some of our cinders had to be teamed four miles.

Section IX.

THE FINAL SUMMARY.

When the job is completed and all accounts are paid, the figures are worked up into a final summary which shows the costs in the same manner as the original estimate. The cost of plant, cement, etc., is added to labor cost of forms, and in general figures are compiled which correspond with the prevailing methods of figuring construction work.

The final summary on the job from which my other exhibits have been taken is not yet made up, so I have taken one from another job, a storage building completed last year. (See Figs. 22 and 23.) It shows the method of setting out the figures so that, at a glance, any of the important details of the cost can be referred to. The final summaries of all the jobs are bound together in a loose-leaf book and are not filed with the job records. They are thus always at hand for ready reference when estimating future work.

Conclusions.

The system has been used by the Aberthaw Construction Company for over two years, and it is interesting to look back and see what results can be traced to an accurate system of Cost Accounting. In comparing my estimates of five years ago with those made to-day, I find that I estimate concrete labor at least 40 per cent. lower than then. On the other hand, I have found that not half enough money used to be figured for plant and tools. Our labor costs on forms have come down over 25 per cent., but I think that most of the saving on this item is due to improved designs and methods of erection than to a study of the unit costs. Steel reinforcement is handled for probably 10 per cent. less than before. Our superintendents have all got a good knowledge of costs, and are really interested in following them from week to week. If a special and unusual piece of construction work is to be built, our men are keen to find out just what it costs.

Some time ago a large job began to show high unit costs; six weeks after the footings were complete the monthly state-

ment showed that labor had overrun the estimate by $10 000. From any point of view but the Cost Accounting, the job looked all right, — well organized, a large force of men all working busily. Each week's report showed unit costs as high as its predecessor. At the expiration of the six weeks the organization of the job was entirely changed; a new carpenter foreman

Job No. 1470 **ABERTHAW CONSTRUCTION CO.** Sheet No. 1

Storehouse in Cambridge Mass

Final Summary of Cost Accounts

		Labour					Material			Plant					
Concrete	Cu yards	Mix & Place	Fill voids	Unload Mtl	Clean up	TOTAL LABOUR	Cement	Aggregate	TOTAL MATERIAL	Labour	Supplies	Rental	TOTAL PLANT		Total Cost per cu yd
Footings	184	44		13	07	81	1 75	1 91	3 66	30	25	33	88		5 35
Walls	102	1 35	34	13	03	1 86	2 01 .27	1 91	4 26	30	25	33	88		7 00
Floors & columns	935	73	11	13	03	1 01	2 02	1 91	3 93	30	25	33	88		5 82
Pent House	9	1 69		13	03	1 86	2 29	1 91	4 20	30	25	33	88		6 94
Cinder Concrete	89	55			03	58	85	44	1 29	30	25	33	88		2 79
Stairs	206 lin	23	1-4 03	005		27	11	07	18	01	01	01	03		48 lin ft
Float Floors	24652°	41				41									4 14 square
Grout over cinder concrete	4940°	50				50	1 24	20	1 44						1 94 "
Rub walls	3080°	3 47				3 47	10		10						3 57 "
Grout Elevator Frames	1..	4 74				4 74	1 00		1 00						5 74 ea
Windows						$ 12									$ 12
Heating Concrete						$361	Coke	[illegible]	$135	Salamanders			$104		$590
Forms	Square Feet	Make erect & Strip	Haul MH	Clean Lumber	Clean up	Total Labour	Lumber & Corr.	Nails oil etc	TOTAL MATERIAL	Labour	Mtl		TOTAL PLANT	Detail Forms	Total Cost per square
	(in per	100	Square	feet)											
Footings	1257	2 12	05	16	06	2 59	2 37	75	3 12	39	15		54	28	6 53
Walls	7486	6 13	05	16	06	7 10	2 37	75	3 12	39	15		54	28	11 04
Columns	5346	9 30	05	16	06	9 57	2 37	75	3 12	39	15		54	28	13 51
Column Heads	•24	5 96				5 96									5 96 ea
Wall Brackets	•34	1 66				1 66									1 66 "
Corbels	•21	53				53									53
Floor slab	17800	3 85	05	16	06	4 12	2 37	75	3 12	39	15		54	28	8 06
Wall Beams	6064	7 57	05	16	06	7 84	2 37	75	3 12	39	15		54	28	11 78
Pent House	343	14 42	05	16	06	14 69	2 37	75	3 12	39	15		54	28	18 63
Stairs	206 lin	38				38	04	01	06	01			01		46 lin ft
Steel Reinforcement	lb	Bend & Place		Unload Material		Total Labor	Steel	Wire	Total Material						Total Cost per ton
		per ton		per ton		per ton									
Footings	5012		3 42		40	3 82	40 52	66	41 18						45 00
Walls	3151		19 77		40	20 17	40 52	66	41 18						61 35
Columns	16566		8 10		40	8 50	40 52	66	41 18						49 68
Floor Slab	67328		5 91		40	6 31	40 52	66	41 18						47 49
Beams	837		5 17		40	5 57	40 52	66	41 18						46 75
Pent House	944		17 27		40	17 67	40 52	66	41 18						58 85
Stairs	835		14 04		40	14 44	40 52	66	41 18						55 62
	206 lin		03			03			08						11 lin ft
Pitch on Basement Walls				$20					$11						$31
Hydrolithic in Elevator pit									$60						$60

FIG. 22

was put on and several other alterations in the force were made, and at once costs began to go down. At the end of the whole job the whole of the $10 000 over-run had been picked up and a saving of about seven hundred dollars made on the estimated labor costs. It is not often that such extensive changes are needed, but often on a job some item runs too high for two or three

Job No. 1970 **ABERTHAW CONSTRUCTION CO.** Sheet No. 2

		Labour			Material					
Drains Excavation	46 c.y.			52						52¢ c.y.
" Backfill	31 c.y.			30						30¢ c.y.
" 5" Pipe	30 lin			03			20			23¢ l.f.
Excavation & Piles			Sublet				$2664			$2664
Miscellaneous excavation & fill by A.C.Co.				$192						192
Grading " "				$201						201
8" Tile Walls	10000 □'	labour &	material	sublet complete	for		27¢	per sq ft		27¢
Brick Piers	750			34185	Brick 16 00	Cement 5 33	21 33			56 18 per M
Platform & Canopy	64 M bd ft	Place 09	Hardware 01½	13 77	Frames 25	Hardware 05	34 51			48 28 per M
Window frames, sash & trim	1500			11			.30			41¢
Roadway	15307			8 88			17 21			26 09 per M
Misc. Carpentry				$162			$13			$175
Inserts	288		24				08			32¢ ea
Door Sills	14		4 07				3 36			7 43
" Frames	6		6 50							
Door frames & guards, stair railing, mouldg erection, ladders etc							$262			$262
Miscellaneous Ironwork			$17				$33			$50
Fire Doors tinned	7						12 44			12 44 ea
Kinnear Doors	7						56 14			56 14 ea
Plumbing						Sublet	$96			$96
Painting							$144			$144
Roofing							$260			$260
Sheet Metal work							$714			$714
Office, telephone, travel etc							$136			$135
Insurance							$340			$340
Surveyor							$11			$11

FIG. 23

weeks. Special attention is given to that item until it is reduced to its normal level. I believe that our system is a reliable barometer, showing from week to week what our jobs are doing. The contractor does not want a post mortem which, however interesting, does not bring back lost profits. He wants to know as the job goes along whether he is making money or not, where his profits or losses are, and whether his losses can be stopped.

Our system is elastic enough to take care of any special situations or furnish any information required. A little time back, I wished to analyze closely the cost of our form work with a view to furnishing our chief engineer with data which would guide him in making the most economical form designs possible. It was a simple matter for me in laying out the code for three jobs to subdivide the form work symbols by adding fourth letters, and get the cost and quantities of posts, joists, mud sills, panels and beam sides, etc., all reported separately and their unit costs worked out, so that we were able to compile data showing how much each post, joist, etc., cost to erect.

Although the system may at first sight seem to be complicated and costly, it is not so in fact. The work in our office is all done by my two assistants, who work with adding machines, and I give not more than one fifth of my own time to supervising and directing it. Our total payrolls in the summer time sometimes amount to as much as $18 000 a week, and this is all handled by these two men without difficulty, and leaves my chief assistant time to visit the jobs occasionally. In the field we spend little more than other contractors do on timekeeping. On a job having a payroll of $1 500 to $2 000 a week, one timekeeper at $15 would give his whole time to timekeeping. All the materials would be looked after by a material clerk at about the same wage. Larger and smaller jobs would have different organizations as their needs required.

I think the difficulties which are hardest to overcome and which need the most careful attention are; *first*, getting the timekeepers interested enough to study their work and divide the time rightly; *second*, seeing that quantities are reported for every item and reported correctly; and *third*, having the

figures handled in the office by men that understand them. My assistants have been picked not from the ranks of bookkeepers but from our own timekeepers. I am sure all the time that they know the meaning of the figures they are handling and can detect errors as they occur.

As I am sure to be asked why I have not mentioned the subject of curves or shown any in this paper, I will anticipate the question by saying that I do not draw curves of any of my cost figures. Where there is a progression in figures or costs between a known low point and known intermediate and high points, a curve may be drawn to find out without mathematical computation the intermediate figures. A great deal of labor may be saved in this way. But, in dealing with contractor's cost, the costs have to be computed first and the plotting of a curve of costs does not save any labor or show any new facts which were not easily discernible by the computed figures. All you get is a wavy line which may be satisfactory to the eye but is of no real use and adds nothing to your previous knowledge. It does, however, give a visual impression which is helpful to some who do not readily take in the significance of figures. In my own work, if I were to draw curves I should have to keep over two hundred up to date by alterations each week and should need a special assistant for the purpose.

For the establishment and conduct of a proper Cost Accounting System on construction work, the chief requisites do not seem to be so much a high degree of technical skill and expert knowledge as much as a common-sense view of the problem to be tackled and patient persistence in working out the details, refusing to be halted by any obstacles. It is easy to pay large fees to experts to install a system. It is not so easy to plug away week after week working out the system, patiently instructing men, detecting errors, correcting them, overcoming opposition, and GETTING RESULTS.

This paper has not been easy to write, and certainly has been very difficult to make interesting. As far as I know, it is the first time that a paper on the principles and methods of Cost Accounting on construction work has been presented, although many have been read on the subject of costs. If this

effort accomplishes anything towards the establishment of accurate and uniform methods of figuring costs in contracting work, I feel sure that my company will not be the loser, and that I shall be more than recompensed for the time put in in compiling these remarks.

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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

BOSTON FOUNDATIONS. DISCUSSION.

By Messrs. Charles R. Gow, L. M. Hastings, F. P. Stearns, E. W. Howe, H. F. Bryant, Henry S. Adams, Ralph E. Rice, Charles T. Main, F. H. Carter, C. T. Fernald, H. E. Sawtell, L. W. Tucker and Granville Johnson.

Charles R. Gow (*by letter*). — The permanent value of Mr. Worcester's paper will be keenly appreciated by all engineers and architects who have to do with the details of foundation construction in this vicinity.

A most extended discussion of its features would seem to be desirable at this time, since, unless the author sees fit in the light of such discussion to modify the conclusions tentatively set forth, they will stand, and justly so, as the most authoritative opinions, on the subjects treated, at present available for this locality.

The desirability of adopting some standardization of practice in foundation requirements as suggested by the author has been long apparent to the writer. A marked divergence of views among engineers and architects as to proper allowances and methods in their design and construction has, in many instances, seemed to lead to unnecessary waste of expenditure, while in other cases a boldness has been shown bordering upon recklessness. It is probably fortunate and to the credit

Note. Further discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before May 10, 1914, for publication in a subsequent number of the Journal.

of the profession that the former type has greatly outnumbered the latter.

Perhaps the most interesting of the author's recommendations are those referring to allowable unit loads on the various soils. The actual loading tests recorded in the paper are, as the author states, probably too few to form a basis from which to draw positive conclusions, but are, nevertheless, of great assistance in arriving at a determination of what may be safe limits for the given localities.

In addition to the tests reported, the writer is able to add the partial results of two such tests now under observation. These were undertaken by the writer in connection with some studies he was making for Prof. W. O. Crosby, of the Massachusetts Institute of Technology, on the sub-soil characteristics at the new Technology grounds in Cambridge. The site was filled to a depth of eight to ten feet with material pumped from the Charles River some years ago. Below this filling there is a deposit of silt and peat to a further depth of eight to ten feet which rests upon a stratum of gravel varying in thickness from ten to twenty feet. Under the gravel is a deposit of soft blue clay extending down to the bed rock or hardpan at a total depth of from one hundred to one hundred and twenty feet.

One loading test was made to determine the bearing value of the gravel stratum and a second to ascertain the supporting power of the clay. The tests were applied as follows: Excavation by means of 3-ft. diameter steel cylinders was carried down to the gravel at a depth of 20 ft., and in the second case to the clay at a depth of about 30 ft.; a wooden box 12 in. square on the inside, with open ends and of sufficient length to reach from the surface to the bottom of the excavation, was lowered into the shaft and erected in its center in a vertical position, a cast-iron plate 12 in. square having previously been bedded on the soil to be tested, around which the lower end of the 12-in. box fitted; a 10-in. by 10-in. post was lowered through the vertical box with its lower end resting upon the 12-in. cast-iron plate and with its upper end projecting above ground to a sufficient height to permit of a platform box being constructed around it; this loading box was partially filled with a cheap concrete weighing

135 lb. per cubic foot. Previous to inserting the post the space between the 12-in. box and the sides of the 3-ft. shaft was back-filled and the cylinders removed, leaving the vertical 12-in. box buried in the ground for its full length.

Owing, probably, to the imperfect bedding of the 12-in. cast-iron plates on the underlying soil, there was in the case of each test an initial reading of one inch of settlement when the load was applied, but no further settlement has occurred, although the load on the gravel was later materially increased and both tests have now been under observation for more than nine months.

The initial load applied on the gravel was five tons, which load was increased at the end of nine days to eight and one-half tons with no resulting settlement. The load on the clay test was five tons and, with the exception of the initial settlement referred to, has shown no further yielding up to the time of last reading. It should be stated that the clay at this particular spot was of medium hardness. It is hoped that observations can be continued on these two tests for at least another year.

The writer is pleased to find the author of this paper recommending somewhat higher unit loads than have heretofore been considered permissible. The suggestion that the stiff clays and hardpans are perfectly safe under unit loads of six tons is in accord with the writer's experience, and he has at times adopted values as high as eight tons for the cemented clays and gravels with no unsatisfactory results. The adoption of higher values for sand seems well justified in the light of experience, although many designers still hesitate to permit as high loading on sand as on the clays. There seems to be no logical reason for discriminating against the coarse sands in favor of clay as a foundation material since the evidence appears to show sand to be the superior of the two as regards ability to support and distribute applied loads without settlement. Undoubtedly this prejudice, where it exists, is often due to a fear of future disturbance of the underlying soil in case other excavations are made in the vicinity. The fact is, however, that the plastic clays are much more susceptible in this respect than are the coarse sands even when they are water-bearing. The explanation of this lies in the well-known tendency of the clays to shrink in volume when

exposed to the drying action of air. Ordinary plastic blue clay contains a large percentage of moisture, stated by some to be at least 20 per cent. by volume. The extraction of this moisture or any appreciable portion of it will cause a corresponding decrease in bulk of the surrounding clay. The result of this action is usually a subsidence of the surrounding soil and consequent settlement of such structures as may be supported by it. Thus in the construction of the East Boston Tunnel it was found that during the construction of that portion built by tunnel methods in lower State Street, the initial settlement was observed in the surface of the street when the work had approached not less than 75 ft. from the point observed, although the work was carried on by the compressed air process and absolutely no ground was lost. The same phenomenon was noticed during the sinking of the pneumatic caissons for the new Custom House tower, in which case the old building was badly damaged by extensive settlements.

It will be argued by many that the extraction of the water from sand will cause a similar action, but the writer has serious doubts as to the accuracy of this assumption unless some sand is also drawn with the water. There is no better known method of consolidating sand than that of immersing it in water, and if the grains are then in a position of maximum proximity it is difficult to understand how the withdrawal of the water from the voids of the sand can bring the particles into any closer relation. It has sometimes been argued that the water in the sand exerts an upward supporting pressure, but this is manifestly impossible since the pressure at the surface of the water must be zero, and at any deeper point the upward and downward pressures will balance each other. It may be that in the case of great loads carried on comparatively small areas, a lateral displacement may result, due to adjacent excavations, but the same result in a more pronounced form may be expected if the material is clay.

The author's recommendation that soft clays be limited to unit pressures of not more than $2\frac{1}{2}$ tons would seem to be liberal, though probably well within the limits of safety, but fine or running sands which are included under the same recommendation would seem to be entitled to somewhat higher values. In view of the common conception of this material, however,

this suggested limit will not be generally regarded as over-conservative.

The treatment of the questions relating to the safe supporting power of piles adds very materially to the present knowledge on the subject. There is, however, some doubt in the mind of the writer as to the wisdom of increasing the value of the *Engineering News* formula by 50 per cent. It should be borne in mind that test piles are apt to be driven with greater care than is ordinarily used, and that results obtained from them may not represent an average. If then, as stated, the value of C appears to be about 4 for settlements of $\frac{1}{4}$ in. in the several tests reported, the adoption of the constant 3 as suggested allows but a small safety factor under the most favorable conditions.

The more or less general adoption in this locality of ten tons per pile as a safe load for spruce piles well driven has proved reasonably satisfactory, and failures of pile foundations have been decidedly uncommon. It may well be, therefore, that we can afford to profit by this experience and adopt more liberal factors in our formulas. Undoubtedly, no set formulas will give uniformly satisfactory results in all cases, and they cannot be expected to replace altogether the good judgment and common sense which, after all, are the most essential requisites for good work of this class. There are probably many more piles seriously damaged by overdriving than were ever left in an unsafe condition due to underdriving. Too often the inspector is content to watch the pile head settle under the successive blows of the hammer without any concern as to what may be happening at the point. There is seldom any difficulty in driving spruce piles into clay even to a considerable depth, and the same is true in some sands. When, however, it is necessary to drive through gravel, it is doubtful if spruce piles can be made to give satisfactory results. It has been the writer's experience that only a small percentage of such piles ever get through gravel to any appreciable depth without showing evidences of breakage, either above or below the ground. Under such conditions oak piles may give much better results, but in very coase material it is doubtful if even they will always answer the requirements. Under some conditions the water jet is an aid to overcoming

this difficulty, and it has been used most effectively in many instances.

Regarding the allowable point of cut-off, it is difficult to see how any fixed grade can be adopted with safety for all localities without being unnecessarily low for some of them. There is unquestionably a tendency for ground waters in this locality to seek lower levels than those formally held. This may be due to various causes, but it is somewhat disquieting to feel that the water level of to-day may be considerably above that of the future in localities where we are relying on its preservative effect in maintaining the integrity of wooden piles.

As to the influence of the Charles River Basin on the ground-water level of the Back Bay district, it should be noted that the marginal conduit as constructed forms a more or less effective cofferdam, shutting off the admission of water from the basin to the land between Charlesgate East on the south and the Charles River Dam on the north. This effect results from the fact that the conduit was constructed within water-tight sheet pile cofferdams which were continuous and were left in place after construction. This piling was driven through the water-bearing seams to the impervious clay below, and upon completion of the conduit the entire area was filled over with a miscellaneous assortment of filling. There would seem to be no good reason why such a structure should not effectually prevent the access of the water in the basin to that portion of the land immediately in its rear. Added to this result is the exclusion of the tide which formerly entered the district through the old sewers and which the new conduit now effectively excludes by means of modern tide gates. It is true that an attempt has been made to introduce water from the basin by means of pipes laid over the top of the marginal conduit and discharging into the vicinity of the old sea wall which formerly marked the boundary between the river and the land. The writer does not understand that this expedient has been entirely successful in reëstablishing the former level of the ground water, although it has had some local influence.

Some years ago the writer's firm made some seven borings for the Charles River Basin Commission, scattered along this

territory referred to, for the purpose of observing the fluctuations of the water levels, and the casings have been allowed to remain in place since for the purpose of continuing the observations. It has been found that in some cases the water has stood as low as grade 3.00,* and in none of the pipes adjacent to the basin has it risen to grade 8.00.* A marked fluctuation has been noted in each case, and the influence of the pipes mentioned above has had an appreciable effect in some instances, but the fact remains that at the present time the water in these borings does not average above grade 6.00.

There is strong evidence to the effect that the leaching action of the sewers accounts for some of the depression of water level, but that this effect should be so general will probably be surprising to many. Readings have also been taken from time to time on the water levels in two old borings on Commonwealth Avenue at Dartmouth and at Arlington streets, and it has in general been found to average lower than grade 8.00, although rising somewhat higher than that at times.

When the writer's firm made the preliminary borings for the Boylston Street Subway, frequent tests of the water level showed it to be almost uniformly at grade 8.00. On the other hand, the writer has found the ground water to stand at grade 5.00 at Stuart Street near Berkeley Street and at grade 6.00 at the junction of Beacon Street and Commonwealth Avenue. The Transit Commission engineers report finding great volumes of water on Dorchester Avenue in test pits sunk by them, which water rose only to grade 3.00. This water was reported as fresh even though occurring within only a few hundred feet of the South Bay, which is subject to the full tidal action.

It should be said in connection with the case referred to on Stuart Street, that although the water stood at grade 5, the old piles which were uncovered had been cut at grade 6.00 and were fully saturated, evidently by capillary action, and were in excellent condition.

There is some reason to believe that not all of the depressions of water levels recorded are due to leaky sewers, for, in the higher portions of the city, there has been noticed a tendency for the

* Referred to Boston Base, which is 0.64 ft. below mean low tide.

ground water level permanently to subside to elevations much below the adjacent sewers. Many instances could be mentioned in which localities that were once found wet at given depths were later found absolutely dry at much greater depths. The writer has always entertained the belief that this lowering was due to the continual increase in the number of deep wells that are being installed from time to time for commercial purposes and that although the water is in general drawn from great depths, it is quite possible that the porous strata used for the purpose may reasonably be expected to connect by means of seams and fissures with the higher strata. While it may not seem logical to many that even such districts as that of the Back Bay, for example, might connect with the underground sources of deep wells, it must be admitted that such water is often found brackish in character, indicating the possibility of such a connection.

In view of the possibilities pointed out above, the writer feels that it may prove to be unwise to deviate from the former practice of cutting at grade 5.00. He has found piles completely decayed at grade 8.00 at E and Second streets, South Boston, at which point the water level was apparently only slightly lower.

While speaking on the subject of piling, the writer desires to raise two points which seem to him to deserve discussion in this connection.

The first question relates to the desirability of stopping the points of piles in the harder crusts when they overlie softer strata, assuming that there is no filling, mud or peat below the pile point where so stopped. In many instances it will be found that piles drive very hard through some of the upper strata, developing resistances which indicate satisfactory supporting power, but after penetrating this crust they will often fail entirely to bring up with the required minimum penetration. Considering that the layer of soil at the level of the pile point must in any event carry the weight which is transmitted to it by the distributing effect of friction on the superficial area of the pile, it follows that the greater the distribution the more load it will sustain. The superior resistance of the hard crusts would seem to indicate wider angles of distribution of the load over the un-

derlying material and a consequent lessening of the unit load upon it. Under such conditions there would seem to be no great advantage in driving into the softer soils as is often required.

The second question relates to the practice of adopting single rows of piles under walls or of single piles under piers. Under ordinary conditions of driving it is seldom possible to bring the pile heads to the exact position desired, with the result that the center of load will be eccentric with the pile, if not entirely off of it. Any influences that tend to induce lateral movement of the supported load will then meet with little or no resistance against rotation about the pile head. It is often argued that piers supported on a single pile or upon a pair of piles can be secured against lateral motion by the tying effect of basement floors. As a caution against this assumption it should be remembered that piles are only necessary as a rule when the soil at grade is unstable, and that under such conditions, a basement floor laid on this soil is subject to settlement and cracking which may render it of no effect as a lateral support. The writer feels that no structure of a permanent character should be made to depend for its stability upon single rows of piling and that piers should rest upon not less than three piles arranged in the form of a triangle. The additional expense necessary to insure safety in this respect will not often be so material as to warrant the possibility of jeopardizing the future safety of the structure.

The danger which the author points out in the case of floors constructed directly upon fill overlying silt or peat is timely and should be considered in all designs where this condition exists. The silts and peats are highly compressible on account of the large amount of decomposed vegetable matter they contain. In their original state of deposit they are semi-fluid and possess no sustaining power. As the accumulations increase in depth the bottom layers are slightly compressed by the greater weight upon them, and when after a lapse of many years they have grown to considerable depths and have in many instances been loaded by the deposit of filling over them, they become quite dense and develop a resistance sufficient to carry the loads that have compressed them, but no more. Any further application of load beyond what they have become accustomed

to carrying will almost invariably produce increased compression to a point where a new state of equilibrium is established.

It has become somewhat common practice in certain sections of the city where these deposits abound to construct buildings, often with no basements and with the ground floors supported on filling which has been deposited on the site to bring it to the floor grade. No matter how carefully this filling has been selected and placed, it must exert an increased pressure on the underlying silt or peat, with the result that the latter is further compressed and a settlement of the floor results. This settlement usually is not apparent for some time after the increased load is applied and is likely to continue for months before finally coming to rest. If the deposits of silt or peat vary in thickness over the lot, the settlement will also be uneven in amount. Even when the load applied is less than that formerly carried, settlements may result from the fact that the new load is transmitted to the unreliable materials in a different manner than was the old load. Under the most favorable circumstances it would seem that these materials should be avoided if possible as a support for any portion of a structure.

The numerous boring records compiled by the author constitute a most valuable reference in convenient form for ascertaining the character of soils that may be expected to be met with in different localities considered.

Prof. W. O. Crosby, in his very interesting article on the geological origin of the Boston Basin, published some years ago, pointed out his belief that the Charles River originally had an outlet into Old Harbor, Dorchester, and that the Merrimac River then flowed into it after passing through what are now the Mystic Lakes and Fresh Pond. The basis for this very interesting hypothesis was the fact that a maximum depression was found in the surface of the bed rock along this route, indicating that at some period in the pre-glacial ages this channel had been worn in the rock by a stream of water.

As tending to confirm this theory it is interesting to study the character of the soil along the route of this supposed pre-historic river. It will be found from a study of these boring records that at the site of the service station of the Edison Company,

on Massachusetts Avenue near Edward Everett Square, the mud was found to extend down to elevation −62, at the corner of Harrison Avenue and Hunneman Street to −43, at the corner of Ruggles and Westminster streets to −45, and at the corner of Riverdale Road and Station Street, Brookline, to −39. If these points are located on a map and connected by a line, it will be found to correspond very closely with the suggested location of this pre-historic stream.

The assumed course of this old stream was shown in the article referred to deflecting to the northward from the last-named point, and we likewise find traces of its former existence in the mud deposits in Longwood playground extending down to grade −20, in Beacon Street near Amory Street extending to grade −26, and in the vicinity of Brookline Street Bridge extending to grade −25. The former course from this point is supposed to have coincided for some distance with the bed of the present Charles River, leaving it again at Allston where the river bends to the northward and passing across the northern portion of Allston and through the Mt. Auburn district to Fresh Pond. There are indications along this latter part of the route similar in nature to those mentioned above of frequent mud deposits of considerable depth, and Mr. L. M. Hastings, city engineer of Cambridge, has found such deposits also to the north of Fresh Pond.

It will be noticed that all of these locations are well inside of the original shore lines as we now understand them and that, therefore, this chain of pools must have at one time formed a part of an inland water course. It is reasonable to suppose that at more or less frequent intervals along the line of this former gorge or valley there was deposited, during the glacial period, the clays and drift which dammed the original river, leaving these frequent pools, which during the succeeding ages have been filled with the wash of the surrounding land that drained into them. Thus we may not expect to find this deep mud condition continuous throughout the entire length, and as a matter of fact we do not. It may well be kept in mind, however, when there is occasion to locate structures in the approximate vicinity of this line, that such conditions as those described above may be expected.

The author refers to a certain general subsidence of the section of Cambridge in the vicinity of Massachusetts Avenue and Albany Street which is said to have amounted to a maximum of two feet in the past ten years. It has been suggested that this action may possibly be explained by the dredging of the Charles River some seventeen years ago and the depositing of the dredged material on the flats, thereby adding to the weight over the soft clay and causing a sub-soil flow toward the river where the load had been lightened. This theory as an explanation is somewhat unsatisfactory for many reasons. Much of the area which has settled is not filled land and is at such a distance from the river that it could hardly be affected by such a condition. Moreover, the total displacement due to settlement must necessarily have caused a marked upheaval of the bed of the river near the Cambridge shore which in all probability would be apparent. Again, the observed subsidence is less at points adjacent to the river than elsewhere, and no lateral movement of the sea wall has resulted as might reasonably be expected if the sub-soil was flowing out from under it.

This section of the city was originally low in elevation and the larger portion has been reclaimed by filling. A large percentage of the area contains a bed of peat which in general overlays a stratum of fine sand and this in turn covers a deep deposit of soft blue clay.

A test boring made by the writer within the past few days near the junction of Albany and Portland streets where the observed settlement is a maximum shows the following condition: 9 ft. of filling, 7 ft. of peat, 9 ft. of fine gray sand, 118 ft. of soft blue clay of the approximate consistency of putty and at least 5 ft. of soft slate.

Mr. F. D. Smith, chief engineer of the sewer division, Metropolitan Water and Sewerage Board, has been good enough to have some new levels taken along the line of the metropolitan sewer in Portland and Albany streets and to give the writer the benefit of the results together with a statement of former readings. These records show that the maximum settlement of this sewer has been at a point near the junction of Portland and Albany streets and that its total amount since the sewer

was built in 1893 is 2.61 ft. below the theoretical grade. A total length of nearly a mile is affected to a greater or less extent.

It is apparent from the settlement records of this section of the sewer that the subsidence proceeded during the first 13.5 years at the average rate of 0.14 ft. per year at the point of maximum depression, that during the next twenty-two months it averaged only 0.08 ft. per year, that for the next year and a half the average per year was 0.11 ft., while for the past four years it seems to have averaged 0.10 ft. per year. While slight inaccuracies in taking these levels due to the strong flow in the sewer and to deposits on the bottom may make the above comparison of figures of little value, there is reason to believe that the rate of subsidence, while not materially checked even at this time, may be assumed to be somewhat lessened. The various records collected by Mr. Hastings also offer some hope of a future reduction in the rate of subsidence.

The great depth of the bed of soft clay at the point of maximum subsidence suggests a relation between the thickness of this layer and the amount of settlement. The action must clearly be attributed to a change in this stratum either in its position or in its composition. The latter theory seems to the writer to be the more attractive one, and he therefore suggests that since the volume of clay depends upon the amount of moisture it contains and as the relative hardness appears also to have a relation to its condition of saturation, if we can conceive of any action which will cause this soft clay to give up a portion of its moisture we can account for the observed decrease in its volume. It is perhaps possible that the vibrations of surface forces may be transmitted to this underlying clay in such a manner as to cause it to quake slightly, in which event there would be a tendency for any surplus water to come to the surface.

The present observed action is especially interesting as offering an explanation of other known settlements of areas which now seem to be at rest. Thus, when we find peat deposits at great depths below the marsh level, we may assume that such settlements as their presence indicates may reasonably have occurred during a comparatively short period of subsidence such as the one we are now discussing. This assumption is strengthened

by the known fact that the peat deposits are usually covered with a deposit of silt, proving that the vegetation was suddenly stopped by a rapid subsidence of the marsh level below the surface of the water. Had the subsidence been as gradual as that which we now assume it to be in general, there seems to be no good reason why the peat should not be continuous to the surface.

L. M. Hastings (*by letter*). — The determination of what may be a proper and safe foundation for an engineering structure, or a building, is one of the most important and sometimes one of the most difficult and perplexing of the many questions which an engineer is called upon to decide, and the two papers on the subject by Mr. Worcester have thrown much light upon it and will prove very valuable additions to engineering literature.

The presence of reliable and easily reached foundations, either bed rock or unyielding soil, in a locality where heavy and important structures are to be placed, at once simplifies the engineer's problem and reduces the cost of the structure itself. There is no doubt, for instance, that the presence of bed rock so near the surface of the ground, found in the larger part of New York City, has saved enormous sums of money in the lessened cost of foundations alone.

This is in marked contrast with the conditions found in many parts of Boston and its vicinity. An examination of the data given by Mr. Worcester in his paper, and any extended experience in designing foundations here, will show that nature has not been kind to us in this respect and that the demands of an ever-increasing population have brought about great changes in the physical conditions in this locality, which have introduced problems and difficulties which did not exist in the earlier days of our history. Great areas of low land, formerly marshes, or flats under water, have been reclaimed by filling on to the existing mud and silt, which in turn is usually underlaid with clay of varying degrees of hardness and often of great depth.

These conditions, which are so common in this vicinity, are especially difficult to deal with successfully even with the expenditure of large sums of money. This has been shown repeatedly in some of the large and expensive buildings, where in

spite of what was thought at the time to be ample provision for stable foundations, settlement has occurred.

The ever-increasing number, size and weight of buildings, bridges and other structures upon these areas render imperative the most careful and intelligent study of all the data which can be obtained bearing upon the case in hand. The supporting power of piles driven into soils such as have been referred to above seems to be one of the factors which is almost impossible of exact determination. Even if they are driven to a fairly hard resistance, unless deep borings have shown that the hard stratum is of sufficient thickness and stability to carry the load submitted to it by the piles, settlement may occur in time.

The comparatively recent practice of testing out the bearing power of a soil by test loads applied for a long time, and under conditions as nearly as possible analogous to those which will exist in the actual construction, has much to commend it. Fairly accurate results should usually be obtained by this method, certainly vastly more reliable than those obtained from any formula, or deductions made from wash borings, rod soundings or test pits.

But even this method has its limitation and may prove ineffective if the whole locality is gradually settling to a considerable depth, as seems to be the case in certain parts of Boston and Cambridge. It may be instructive to describe briefly some of the observed facts about this rather curious and interesting case in Cambridge.

The affected area is shown on Fig. 1, one axis extending along Massachusetts Avenue from Harvard Bridge to near Central Square, and the other from Albany Street, at Pacific Street, marked [10], to the junction of Portland Street and Broadway, marked [11]. Within this district noticeable settlements of the ground and buildings have occurred, the maximum being found near the junction of Portland and Albany streets. The metropolitan sewer, built largely of brick and 48 in. by 54 in. in dimensions, extends the entire length of both Albany and Portland streets and was built in the natural soil, largely sand, without piles, in 1893, at about elevation −5.00.* A settlement in this

* Referred to Cambridge base.

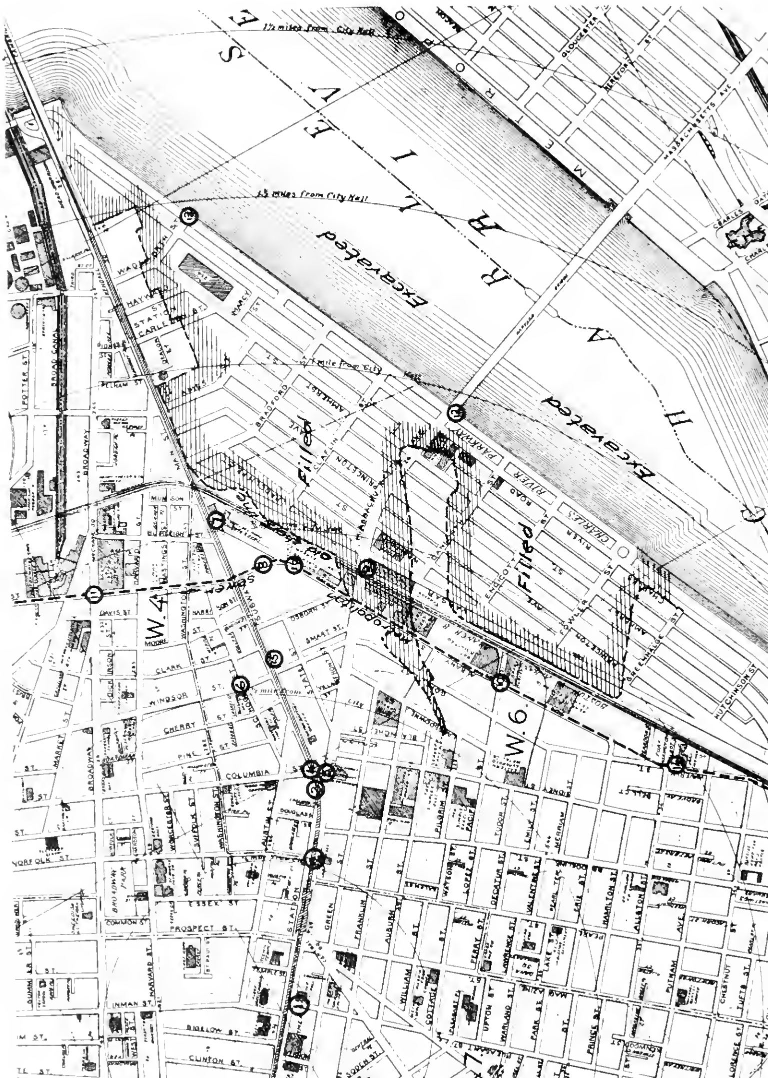


FIG. 1. MAP OF A PART OF CAMBRIDGE.

sewer begins at about Pacific Street [10] and reaches a maximum at the point marked [8], where the sewer is now about 2.60 ft. below its original grade as laid in 1893. This settlement gradually diminishes toward the northeast until at point [11] the sewer is at its original grade.

Directly alongside the metropolitan sewer is one built by the city of Cambridge on piles in 1882 and at about elevation 5.00. At the point marked [16] in Albany Street, this sewer has settled about 3.00 ft. from its original grade.

The brick building of the Metropolitan Storage Warehouse Company, marked [9], and built upon a pile foundation, is now 1.18 ft. lower than it was in 1897. The Odd Fellows Hall building, of brick, placed upon a natural sand foundation 10 to 12 ft. below the surface, marked [2], has, since 1898, settled 0.82 ft. The brick building at the junction of Main Street and Massachusetts Avenue, marked [5], built without piles on sand, has settled 1.30 ft. since 1898. The two points on the sea wall at [12] and [13], and most of the wall between, show very little settlement but, at one point, where an old creek entered the river, the wall has settled more than a foot.

Numerous other points have been observed, all tending to show that the settlement diminishes from the maxima at [8] and [16] to the boundaries of the district.

Fig. 2 is a profile on the line of Massachusetts Avenue to the Boston & Albany Railroad and thence produced southeasterly to the river channel, compiled from such data as were available.

This shows that a deep bed of clay underlies the surface materials, and extends to bedrock. Much of this clay was found in the borings to be soft and putty like. The surface materials are filling, mud, sand and gravel.

The area between the sea wall and the Boston & Albany Railroad was filled largely by hydraulic dredging from the river flats. These flats were excavated to a level about 20 ft. below mean high tide, or about 10 ft. below the surface of the flats. Upon the tract northwest of the Boston & Albany Railroad, much of the land has been raised somewhat in grade by filling, and many large and heavy buildings for factory and other pur-

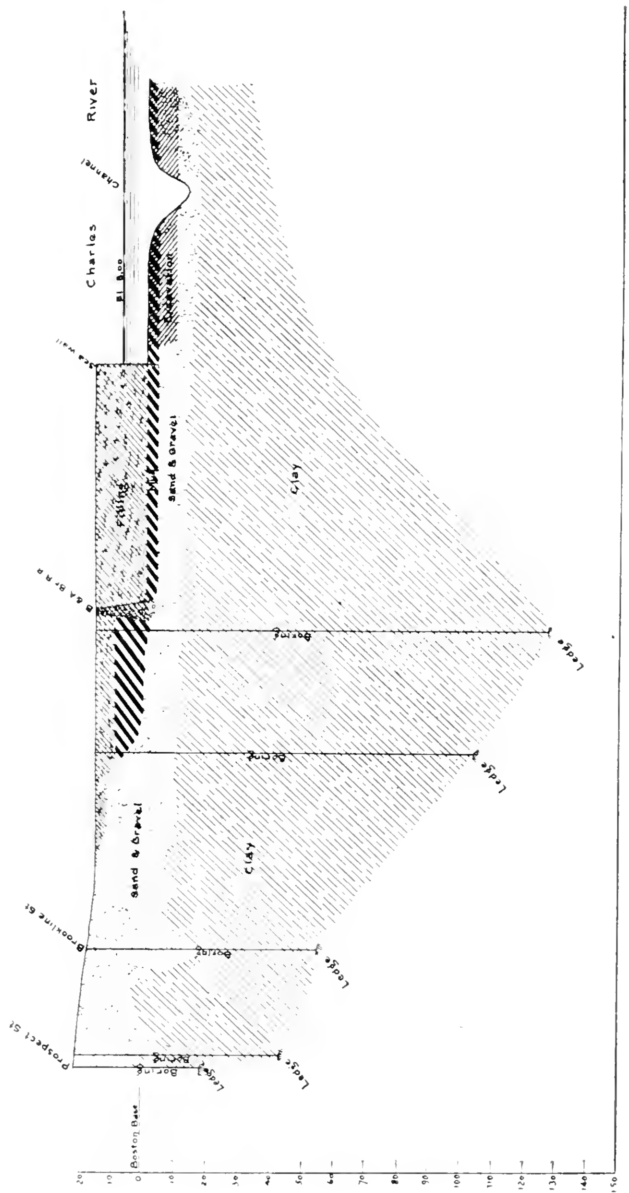


FIG. 2. PROFILE ON MASSACHUSETTS AVE.

poses have been erected in the last fifteen years, while traffic on the streets has correspondingly increased.

To explain the movement as observed above, two theories suggest themselves, neither of which is entirely satisfactory. The first and more obvious one is that the increased weight upon

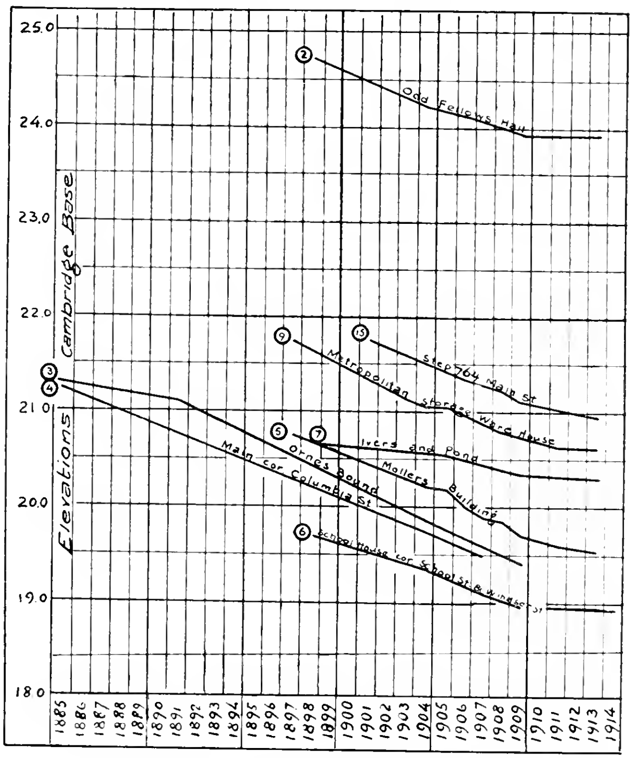


FIG. 3. DIAGRAM SHOWING RATES OF SETTLEMENT OF POINTS IN CAMBRIDGE.

the area occasioned by filling, buildings and street pavements, with the impact of traffic, cars, etc., has caused progressive compression of the underlying clay stratum which shows itself by the settling of surfaces and structures whether carried on piles or not.

The lack of movement at [12] and [13] and at other points

between them might be partly explained by the fact that the material there is somewhat harder than elsewhere.

It seems difficult to reconcile this theory with the behavior of the roadbed of the Boston & Albany Railroad. This road was built about 1860 upon a heavy fill across the flats and marsh, and the point of maximum settlement at [16] is within 200 ft. of the road. Since its construction this road has been in operation as a freight road entirely. It would be expected that the limit of compression due to the filling load and impact of trains would have been reached long ago, and that little movement would appear in recent years. As a matter of fact, however, the track at and near the Massachusetts Avenue crossing has settled, as nearly as can be determined, the same amount as the street itself, which was filled about 1890, and opened for travel in 1891, and is now about 1.60 ft. below its original grade. The conditions on Main Street from Lafayette Square to the railroad are much the same. The street was opened for travel in 1793 and has been in continuous use. In 1873 a 36-in. brick sewer was built in the street, mostly on sand, and it is now found to be from 1.20 to 1.75 ft. lower than it was when constructed.

The other theory is that the dredging from the river and the placing of this material and other filling, together with buildings, traffic, etc., upon the tract where the original grade has been substantially raised, has produced a condition of unbalanced loading, causing a movement of the mobile materials, such as soft clay, toward the river where the pressures are less, and so a lowering of the entire overlay of harder material where this movement took place.

While most of the observations would support this theory, it seems difficult to harmonize the slight settlements noted at [12] and [13] with it.

Whatever the cause may be, if the settlement continues it will be a fruitful source of expense and trouble in the future.

Frederic P. Stearns. — I wish to add, to what has been said, my own impression of the paper presented here to-night. It represents a vast amount of labor expended for the general welfare, and the Society is to be congratuated upon receiving it.

The paper asks for discussion bearing upon the question of

the height of ground water. I have been interested for many years in the ground-water levels in the Back Bay, but my information regarding these matters is not up to date.

In 1878, when the preliminary investigations for the Main Drainage Works of Boston were in progress, the question was raised as to whether a low-level system of sewers would not lower the ground-water level in the Back Bay to such an extent as to cause the decay of the piles supporting buildings, which, under the city regulations, were required to be cut off at grade 5; that is, at 5 ft. above Boston city base, which is somewhat below mean tide level. At that time pipes were driven into the ground at many places in the Back Bay and it was found that the soil water was nearly level at grade 7.7. It was also found that the soil water rose and fell, responding quickly to any rain or melting snow, and that the variation was very nearly uniform over the entire district. It is further stated that the extreme rise due to 4 in. of surface water was one foot.

These observations extended from January 17 to March 11, 1878, during a period when there was an unusually large precipitation, the total during January and February at Chestnut Hill being 12.93 ins. and at the sewer yard, Boston, 13.38 ins., with one rain in February amounting to 2.70 ins.

In 1885 these observations were repeated after the Main Drainage Works had been in operation more than a year, and the ground water was found at practically the same level as in 1878.

Still later, in January, 1894, I had occasion, in connection with the project for the proposed Charles River Basin, to again determine the ground-water levels in the Back Bay. The measurements were made at some of the pipes used for previous measurements and at many additional places. It was then found that the average height of the ground water was substantially the same as on the previous occasions, but exceptional cases were found where the ground water was much lower, in some places below grade 5, indicating that the level had been reduced locally by drainage into low-level sewers or by pumping.

The noticeable feature of the observations is the general uniformity of level and the absence of any slope toward the Charles River, which might appear to be the natural outlet for

the ground water. These facts indicate that the ground-water level is governed by leakage into the sewers, and that over the greater part of the district there is no percolation towards the Charles River Basin. They also indicate that the governing leakage is into many sewers at a comparatively high level, rather than into a few sewers at a low level. Indeed, it seems highly probable that the level in most places is governed by leakage into the house drains or into the minor sewers and not by leakage into the main sewers.

If this supposition is correct, the ground-water level of the Back Bay in the future will depend largely upon the opportunities afforded for leakage into sewers and other structures and upon the changes in conditions that are likely to take place.

What are these conditions?

The Charles River Basin, instead of fluctuating with the tide, is now maintained constantly at grade 8, which might appear to be a condition favorable for maintaining the ground water at that level, but the Charles River embankment, built for a width of 100 ft. outside of the old retaining wall back of Beacon Street, acts as a dam. Within the embankment is a marginal conduit, in which the water is maintained at a low level by means of tide gates. The old sewer outlets connected with this conduit were leaky, at the time of the completion of the basin, so that they drained the old dry rubble retaining wall just mentioned to such an extent that the water in the interstices of this wall stood several feet below the water in the basin. It was then suggested that the sewers be rebuilt and made tight or that pipes be laid from the basin to the wall to maintain the water level at the wall at grade 8, and I understand that the pipes for this purpose were laid.

The building of the subway in Boylston Street has required the temporary removal of much ground water and it is not probable that any subway when completed can be made absolutely water-tight.

A new system of sanitary sewers in the Back Bay district has been built in part. During such construction, the ground water is temporarily lowered and, as I understand the matter, these sewers are at a low level.

It was formerly a requirement, and still may be, that cellars in the Back Bay shall not be lower than grade 12, but in these days, when high buildings are being constructed and foundations can be "water-proofed," cellars are being constructed at a lower level and the drains from the buildings which are not likely to be made watertight will probably be at a lower level than those heretofore laid.

All of these changes will tend to lower the level of the ground water in the Back Bay, and such lowering will take place unless more water is supplied to the ground to offset such additional leakage.

The source of water supply at present is the rainfall and the leakage from the water pipes, with possibly a small additional amount from street and lawn sprinkling. Of the rainfall on this area, the portion which goes into the ground is decreasing, as vacant lots are being built upon and the roofs are drained directly into the sewers. This change is now taking place quite rapidly where the land was formerly occupied by the Boston & Providence Railroad. All of the changes which are taking place in this district appear to be in the direction of decreasing the amount of water which will find its way into the ground.

These considerations lead me to believe that piles to support important structures should be cut off below rather than above grade 5.

Referring now to the maximum head which must be provided in building waterproof basements in this district, it seems to me that the many outlets, which have maintained the ground-water level in the Back Bay at a nearly uniform elevation in the past, will prevent it from rising much above this level.

The results of measurements in 1878, as already stated, show that after very heavy rains the ground water rose only a foot, or to about grade 9, and it does not seem probable that the water would rise under any conditions of rainfall more than half a foot, or a foot, above this level in any part of the district well provided with house drains. The water in the sewers, when they are flooded by heavy rains, especially if such rains occur when the Charles River Basin is above its normal level, may rise as high as grade 10, or possibly grade 11, but unless there are

opportunities for the water in the sewers to communicate freely with the ground under waterproofed basements, it is not likely that the ground-water level would rise to the level of the water in the sewers.

Edward W. Howe.—Mr. Hastings' experience has been about the same as mine in the Back Bay territory. We have taken a great many borings in the neighborhood of the Back Bay Fens, and the general condition shown is that there is a layer of hard gravel overlying, at various depths, soft clay which reaches to a considerable depth. It has been found that the best foundation is secured by not driving the piles through the gravel layer. Notwithstanding that the gravel appears to give a firm footing for the piles when driven, there is a continuous settlement. One example of this was very marked. At Charlesgate West there is a bridge over the Boston & Albany Railroad, built in 1882. It was built to about grade 35, with pile foundation, the piles driven to about grade −27 or −28, the borings having showed the gravel layer to be from 4 to 6 ft. in depth underlaid by clay. That bridge had not been built a great while before there were complaints that the ventilators of passenger cars were being knocked off. Observations have been taken on that bridge constantly from that time to the present and have shown constant settlement. One would suppose that it would reach a bearing eventually, but it has not yet. The diagram representing the rate of settlement shows practically a straight line, indicating a constant and uniform settlement, and the worst corner has gone down 3 ft. 8 in. in thirty years. The bridge was raised about 20 in. in 1895 and it has just been raised again. Not only the bridge, but the streets, the approaches and everything around there, have gone down.

At the bridge over the park waterway at Commonwealth Avenue we had a similar bottom and I remember distinctly the pile driving there. At about grade −10 this gravel layer of about 4 to 6 ft. in depth was found; below this to grade −75 was soft clay. The piles drove very hard through the gravel, but after penetrating through it they would go down 6 in. at a blow. We drove as long piles as we could find without

getting any greater resistance to driving than was met at the top of the gravel.

Now the mystery is, if this large area is going down, where has the material gone to in all these years? There must be something more than squeezing the water out of it, for it would seem as though in that case, as the earth became more solid, the rate of settlement would decrease, instead of which the settlement is as rapid now as it was thirty years ago. I looked at Mr. Worcester's record of borings in that vicinity. The nearest one to the bridge over the railroad was about 150 ft. away, and that shows filling down to grade 0, then mud to grade −10, then soft clay. Another boring is 250 ft. away near the new subway, and this shows loose sand and gravel to −7, coarse sand to −12, coarse sand and a little slit to −14, a little peat and fine sand to −26, sand and gravel to −29, clay to −30 and then a stiff blue clay. All around that locality about the same condition is shown. The levels on the buildings which have been built close by there showed a settlement of about 6 in. in about two years. One peculiar feature of the settlement of the Charlesgate bridge was that the abutments as they settled spread apart, the masonry tipping back against the backfilling. The only explanation of this that seems plausible is that the flats on which the abutments were built having been only recently filled, the toes of the abutments were on more compact ground than the backs and the backs settled more.

Henry F. Bryant. — It is a pleasure to testify to one's appreciation of the paper presented by Mr. Worcester. It is timely and sound and represents a tremendous amount of labor in collating valuable information. Our thanks are due him.

The late arrival of the Journal containing the paper made formal written discussion impossible, but I am glad of this opportunity to record the thoughts which came to me as I first read it.

I concur with Mr. Worcester's intimation that the Boston Building Law, with relation to reinforced concrete, should be materially modified. While discretion in the hands of the building commissioner has so far made it possible for one to follow conservative up-to-date practice, and while I believe that

there should always be a certain amount of such discretion available, I think that the Society would do well to appoint a committee with full power to proceed along usual channels towards such a revision. I doubt the wisdom of the Society, as a whole, taking action in this matter by discussing details.

In the subsidence of the areas in Cambridge, pointed out by Mr. Worcester and Mr. Hastings, there is considerable food for thought concerning the cause. My impression is that this subsidence, like that at the Charlesgate bridges, mentioned by Mr. Howe, and that in Copley Square, mentioned by Mr. Worcester and others, is largely due to the compacting of the soft clay. I am without definite figures, but I suspect that a careful study of the situation will show that the settlements in Boston, at any rate, have been greater under the deep fills and heavy buildings than under the adjoining areas.

For instance, the Charlesgate Boston & Albany Railroad bridge abutments tip backwards against the fill, due, in Mr. Howe's opinion, to the weight of the backfilling having carried these rear piles downward, the front piles next the railroad being less affected. This condition was most noticeable at the outset, but I feel that, if there was a lateral movement of the soft clay, it would have been somewhat general and the railroad would have gone down with its immediate surroundings.

The tendency of this soft clay to settle under load must be considered in designing foundations. In my judgment, buildings on this area should have a deep, thin foundation wall, preferably supported on a single row of piles, reinforced and of considerable depth in an attempt to make them incapable of vertical deformation under superimposed loads.

The interior piers should be provided with piles in the usual way in an attempt to get a uniform pile loading throughout the structure. These piers should also be carried to the side walls by thin, reinforced cross girders of maximum depth. Such a structure would act like a ship and would float in a sound condition even though not on an even keel. Of course an attempt should be made to obtain a uniform load distribution, and care should be taken to prevent excessive loading at any point from the surrounding fill.

The Hotel Canterbury on Charlesgate West, built perhaps fifteen years ago, under my advice, but not under my supervision, had the type of foundations mentioned. I have no records of its settlement. It has been continuous and Mr. Howe mentions that it was about 6 ins. in two years.

On the opposite side of Newbury Street, the Nurses' Home is similarly designed but with a lesser depth of foundation girders and was completed this year. I expect the same settlement here and trust that it will be equally uniform.

There are no apparent settlement cracks in the Canterbury although the rear corners rest on the railroad fill.

Mr. Worcester suggests that peat at considerable depth indicates land subsidence. I accept that statement with some hesitation. In the case of fresh water peat, that is certainly not the case, as we find it to depths of forty, seventy and even one hundred feet, completely filling old glacial pot holes. I have in mind one or two instances of tidal marshes where the subsidence would of necessity be quite irregular had the bottom of the peat ever been at or near the surface. I think that the evidence is favorable for Mr. Worcester's theory, but I do not think it is by any means proven.

The appearance of silt overlying peat is new to me, but gravel on top of peat, particularly along the shore line of pot holes, is very common. Nothing but a boring will detect this.

Mr. Worcester is apparently more optimistic regarding the beneficial effect of the Charles River Basin than I am. So far I have failed to find but very few examples of its helpfulness. One was at the corner of the Parkway and Revere Street in the West End. We found ground water at grade 7 near the Parkway, but at grade 2 in the vicinity of Charles Street. The higher level was undoubtedly due to a supply from the basin or from the park, quite likely the former because of the presence of old dock walls which would readily convey the water from the basin inward. The lower grade was undoubtedly due to leakage into the interceptor. The Sewer Department and I have recently made investigations with relation to the ground water heights along Back Street, on the Back Bay. The subway pumping materially affected these observations for a time, making

it quite evident that in spite of the ground water pipes put in directly from the basin, to supply the water to the soil, the subway pumping took away the water faster than it would come in.

At other times it has been apparent that the Back Street sewer, which was running full, was undoubtedly draining the ground, possibly through the medium of the house connections. This may be an unusual case, but I am confident that it is not possible to maintain tight sewers and connections even with the best skill and supervision now available. I feel, to paraphrase Lincoln, that we can build part of a sewer tight all the time and all of a sewer tight part of the time, but we can't build all of a sewer tight all the time. For this reason my practice has been to adopt a cutting-off grade largely fixed by the elevation of the neighboring sewers.

In the majority of the localities in Brookline I have cut off twelve inches above the sewer level. In Boston, the presence of the intercepters has not made this possible. In one case, on Norway Street, it was found necessary to cut off at grade 1. In the Fenway section and along portions of Beacon Street the ground water elevation has been such that grade 5 to 7 has seemed to be the proper cutting-off grade. Grade 6 has probably been the average. I should advise against adopting any such grade as 8 for universal use, although I believe that Mr. Hodgdon's grade at the docks is entirely proper, i. e., grade 9.

In stating the above, I recognize the fact that ground water will protect the pile considerably above its actual level, probably due to capillarity. One pile, on Oneida Street, just examined and reported to be seventy years old, was perfectly sound with its top at grade 16. Another pile on an adjoining building, only a few feet away, was completely decayed and useless above grade 11 or 12. This pile was only about two years old. I mention these instances to illustrate the unwisdom of expecting piles to remain sound much above ground-water level.

To overcome in a measure the cost of cutting off at low grade I have made use, for some years, of concrete pile extensions. These have met with some opposition from the Building Department of the city because of the theoretical lack of lateral stability. I refer particularly to the use of headless barrels for

forms, one barrel being placed over another where necessary. As a practical matter, these barrel extensions are much safer than those piers which have their forms removed before back-filling, for the reason that they are never disturbed after being poured. Likewise, as a practical matter, the lateral stability even when no large-sized piers are used is more than ample. This is due to the surrounding earth in part but mainly to the fact that the extensions bond well to the pile head and to the superimposed concrete beams. They are also slightly inclined, particularly in a longitudinal direction. Such inclination is not enough to cause any lateral pressure on the pile heads unless they have such a lateral load as would produce that pressure in any event. After fifteen or twenty years' use of this method, I am absolutely convinced as to its stability as well as economy.

I agree with Mr. Worcester that no basement floors, unsupported, should be laid on soft peat. I do think, however, that for dwelling houses or apartment hotels, basement floors can be floated on hard fill where the amount of underlying peat is small.

I hesitate to accept Mr. Worcester's figure of grade 12 for maximum hydrostatic pressure on basements, and think that the circumstances in each case should be the sole guide. I am confident that grade 12 is altogether too high for the Back Bay. Some of the records of surface water levels in the sewers and marginal conduit show a height, as I remember it, of grade 12 or 13. Back yards of dwellings in the immediate vicinity, which were connected with these sewers, were not flooded, although their surface was as low as 10 in some cases. I have no explanation of this apparent anomaly but believe that whatever that explanation is will apply to the pressure on low basements.

Concrete is the material of all materials for foundations. It is, I believe, more suitable for that than for any other purpose, but intelligent supervision is, as Mr. Worcester states, absolutely essential. Such supervision is particularly required in cold weather such as has just passed, and, while I am not a believer in having too many rules to govern our conduct, I believe that the building law should provide something definite in this respect. I would make it compulsory that no concrete should be laid without special permission from the building commissioner,

unless the thermometer was, and had been for two hours, above 20 degrees fahr. and unless the temperature of the mix remained at or above 38 degrees fahr. for two hours after placing.

The figures on safe loading on soils appear to me as being reasonably conservative and yet not unduly so. I think that there are plenty of bowlder clays in the Boston drumlins which are capable of being loaded with safety to 8 or even 10 tons per sq. ft. I have frequently used the 8-ton figure where occasion warranted.

Mr. Worcester's figure of $3\frac{1}{2}$ and $2\frac{1}{2}$ tons on the medium and soft clays, I have been in the habit of making 3 and 2 tons, sometimes as low as $1\frac{1}{2}$ on the latter. Such tests as I have made would make me a little slow in adding that additional half ton.

I agree thoroughly with Mr. Worcester's analysis of the penetration formula for piles, called the *Engineering News* formula, and think that the use of the coefficient 3 instead of 2 is entirely justified in the majority of cases. This formula, as we all know, cannot be used in a great many cases. For instance, deep penetration into the softer sands permits a heavy loading, although the formula shows a weak pile. Against sharp resistance, with little penetration into a crust over soft bottom, which permits only a light loading, the formula shows a much greater bearing power than is safe.

If we adopt the coefficient 3, we must still further restrict the application of this formula and for that reason I am inclined to leave it as it is, expecting some liberties to be taken with it in normal cases.

The only point in which I really differ from Mr. Worcester is in the friction figure which he terms "coefficient per square foot." He, however, states that "it is not always safe to take into account the portion of the pile which is imbedded in an inferior material." I do not think that the imbedment in inferior material should ever be considered as a factor in increasing supporting power. In fact, I think that with a layer of soft material underlying a considerable depth of hard filling, the latter should be considered as negative since it is likely to sieze the pile and, in settling, to push it down. This has occurred several times in my observation.

Instead of Mr. Worcester's coefficient, I suggest the use of 1 000 lbs. per sq. ft. on that portion of the pile which is in the supporting soil. This for a pile having an average diameter of 8 ins. means about one ton per linear foot of pile in the supporting medium. From this I would deduct a similar amount for penetration in filling underlaid by any considerable depth of peat or silt.

The above figure is supposed to be 50 per cent of the actual skin friction, ignoring the bearing power of the point, which is, of course, quite small in soft material. I have used this rule for twenty years with heavily loaded piles, some of them carrying as much as fifty tons, and I have never seen a suspicion of weakness.

With Mr. Worcester's suggestion for the use of borings, I am in very close agreement. I believe that borings should be required by the Building Department wherever the bottom is not fully known or where there is a suspicion of underlying soft material. It may not be necessary to put this into the laws, but it should be thoroughly understood and expected by builders.

HENRY S. ADAMS (*by letter*). — I have read with great interest the paper by Mr. J. R. Worcester on "Boston Foundations," and his observations and conclusions are so nearly in accord with my experience that I can add but little by way of discussion.

It might be interesting to note that the material found in the excavation for the Siegel building, at the corner of Washington and Essex streets was very similar in character to that found in the Jordan Marsh building on Avon Place. The fine sand lay in a bed from 2 to 4 ft. thick immediately above the clay, at a depth of about 26 ft. below the elevation of Hayward Place. This sand would stand vertical, sometimes for several days, but ultimately would begin to flow from the bottom and cave in, acting in a manner similar to clay.

We have all had the experience in driving piles along the water front of finding extremely soft spots close to a harder material. In many cases I have found by a study of old maps that these soft places are the beds of ancient creeks, and I find it very instructive to locate, as far as possible, the old creeks

through an area in which it is proposed to drive piles. One of the most notable examples is in the Mystic River where, in building a bulkhead, the line crossed the ancient bed of the South Channel through which it was necessary to use 45 to 50 ft. piles, instead of 30-ft., which we used on both sides of the creek. I have had the same experience in South Bay.

On the subject of cut-off for piles, I think the position taken by the Building Department at the present time, of "show me," is better than adopting any hard and fast rule. In other words, they will permit any reasonable elevation for cut-off when shown the permanent elevation of the ground water.

On Pier 6 at South Boston, known as the Fish Pier, we adopted grade +9 as the cut-off, but on the south side of Northern Avenue we are using +8, although there are some indications that this elevation is considerably below the natural level of the water. Excavations made a year ago indicate that the water stood as high as grade 12 in some portions of the land.

It seems to me that the best way to determine the cut-off is first to find the elevation of the ground water, and from that the cut-off.

I have observed from time to time many examples of the subsidence of fills, especially over silt. It was found on filling the land in Cambridge upon which the Technology buildings are to be built, that there was a loss of about 25 per cent. of filling material, due to the compression of the muds and the gravel sinking into the mud. There are places in Goff's Cove where there were 30 to 40 ft. of mud and where I understand the borings show gravel at the present time.

In Charlestown about the same results were observed in filling 6 acres. I found there, that at the end of two years, the surface had settled nearly 2 ft. and is still settling to some extent. I think that Mr. Hodgdon can give us some very interesting data in relation to the settlement of the South Boston flats.

It has been my experience in filled areas that after a time the material has settled away from under the piers, leaving the entire load carried by the piles; and for that reason, in putting

in the foundations for the buildings on the Fish Pier I have made no allowance for any load to be carried by the fill. The entire load is on the piles, and in figuring the piles I have assumed that the material of the fill and the underlying mud or silt have no sustaining power, but will, on the contrary, tend to pull the piles down as the material settles; therefore I rely entirely upon the clay for supporting the buildings.

I have found in driving piles along the water front that a 12-ft. penetration into the average clay is safe for about 10 tons, and 20-ft. into similar clay is safe for about 25 tons. Such clay is commonly marked in borings "blue clay," or "stiff blue clay," and will give a uniform penetration for a pile of about 4 in. to a blow under a 2 800-lb. hammer falling 10 ft. The usual method that I employ for testing a pile is to let the pile set in the ground for at least twenty-four hours and then resume driving, taking the penetration for the first four blows, and using the *Engineering News* formula to obtain the sustaining power of the pile.

I think it is very important to make the tests after the pile has set, and not immediately after driving. It takes a period of time for the clay surrounding the pile to grip the pile. Such tests usually show that the pile will sustain, after a twenty-four hour set, three to four times the load that it will when first driven. As nearly as I can estimate it, the clay, after having thoroughly set, has a grip per square foot upon the pile of about one third of the load that we would ordinarily place upon the clay for foundation. For example, if the clay is good for 3 tons per sq. ft. for foundation, it is good for about 1 ton per sq. ft. in grip upon the pile.

As moist clay acts as a fluid, I have often figured that it is not safe to put upon clay a much greater load than the weight of the material over the clay, because clay has a tendency to flow upward as well as sideways. There is danger in driving piles in clay of putting the piles too close together. The old rule that was taught me when I first went to work, that piles should not be driven into clay closer than 3 ft. on centers, I think is a safe one. If they are driven closer than that in clumps, the material between the piles is so compressed that

it loses its grip, and does not hold the interior piles to the extent that it should.

The modification of the *Engineering News* formula for the supporting power of piles, as suggested by Mr. Worcester, seems to be a good one for the material around Boston.

In practice, I do not think it is safe to figure a load of over 10 tons on the ordinary spruce pile, but on oak piles I have allowed loads as high as 30 tons. Where the water is so deep that a pile would not be safe for such a load if used as a column, I figure it as a column only, and not a pile.

It might be interesting to read from the records of the Proprietors of Long Wharf the story of one of the earliest borings:

"Long Wharf Well."

"The depth of the well is 35 ft. From the bottom of the well to the spring is 62 ft., making 97 ft. from the top of the well to the spring. The inside curb which forms the well is 4 ft. in diameter on the inside and perfectly tight at the bottom. In digging the well from the platform which now covers it, we dug through the wharf about 16 ft., thence through the flats 14 ft. We then came to a marsh of about 6 ins. in thickness under which was pure clay. We dug into this clay about $4\frac{1}{2}$ ft. and then put down the inside curb. In boring for the fresh water we proceeded as follows:

"We first made a hole in the bottom of the curb $10\frac{1}{2}$ ins. in diameter; then bored into the clay 8 ft. with an auger 10 ins. in diameter. We then took a log 15 ft. long and 10 ins. in diameter with a hole through it of 5 ins. diameter which we put into the hole at the bottom of the curb and drove it with a large iron weight 13 ft., leaving 2 ft. above the bottom of the curb; then with an auger 5 ins. in diameter bored through the hollow log 35 ft. from the bottom of the well through pure clay. We then came to sand from which we had a small quantity of fresh water. Through this sand we bored about 23 ft. and then came to pure clay. We bored through this clay about 7 ft. and came to a hard pan of slate and on taking up the auger found the water to rise fast. We then put a tube $4\frac{1}{2}$ ins. in diameter into the hole we had bored, which hollow tube extends from the bottom of the well to

the hard pan of slate. We then fixed a drill on the shank of the auger and let it down through the hollow tube and drilled into the hard pan bottom about 3 ft. We found we had struck a spring affording an abundant supply of water. The well at Long Wharf was begun Monday, June 12, 1797. Began to bore for a spring Monday, Sept. 4; got to the spring Wednesday, Sept. 6, at 11 o'clock; put in the pump Saturday, Sept. 9, at 12 o'clock. Began to receive pay for water Monday, Sept. 11, being just three months from the time it was begun."

This well, which was situated about 150 ft. east of Atlantic Avenue, was cut off by the East Boston Tunnel.

RALPH E. RICE (*by letter*). — Mr. Worcester describes, in the division of his paper entitled "Pressure on Soil," what he considers the best way to make a test of the bearing power of soil. The Boston Elevated Railway Company made three such tests, preliminary to the construction of the Cambridge Main Street Subway, in that section of Cambridge that is and for years has been settling, using the method suggested by Mr. Worcester.

Mr. L. M. Hastings, city engineer of Cambridge, has fully described the geological formations between the Charles River and Central Square. In the forty years between 1869 and 1909 the surface at Lafayette Square had settled 2 ft., while at Central Square, 1 300 ft. west, there had been almost no settlement. At Brookline Street between these two points and about 500 ft. from Lafayette Square a wash boring shows 96 ft. of soft clay before hard material is reached. This condition warranted a careful study of the bearing power of the soil in the subway location.

The test made at Lafayette Square was typical of the three tests and will be briefly described. The object was to determine the bearing power of the soil at the elevation of the bottom of the invert of the proposed subway. A pit 7.5 ft. wide, 9 ft. long and 24 ft. deep was excavated and sheeted and near the center of the bottom a hole 3.5 ft. by 3.5 ft. by 2.5 ft. was carefully dug into the undisturbed clay and a box of 2-in. plank 3 ft. by 3 ft. by 3 ft. outside dimensions, without top or bottom, inserted. Spikes were driven into the inside of the box so as to protrude about 2 ins., six or eight being driven into each side to act as a bond

between the box and the concrete which was placed in it. The concrete and the box would then act as a unit and form a foundation 3 ft. square resting on the undisturbed soil.

On the bottom of the pit, which was leveled off, were placed timbers and a flooring, built as tightly as possible and firmly braced from above to prevent any upward movement which might be caused by the pressure. Several $\frac{1}{2}$-in. observation holes were bored in the flooring to permit detection of any movement of the soil underneath. The ground water was kept pumped out by a steam pump.

Four upright timbers were placed on the top of the concrete foundation to support a box, 7 ft. square, made of 2-in. plank which contained the load of earth, the material excavated from the pit being used. This superstructure was centered over the center of the foundation. Lateral spreading of the box was prevented by stretching two sets of No. 10 gage wire both ways across the box.

A gage box of convenient size was made and the amount of earth sufficient to fill it was weighed on platform scales, enough earth being placed in the box to make, with the wooden structure, a load of about 2 000 lbs. per sq. ft. on the soil. Elevations were read on a spike in the top of a 4-in. by 4-in. post attached to the floor and extending perpendicularly in the center of the box.

The load was increased daily about 1 000 lbs. per sq. ft., observations being made about fifteen minutes after each increase of load and every night and morning. When the load had reached 6 tons per sq. ft. the box was about 11 ft. above the surface and leaned from the perpendicular about 5 ins. in 15 ft., and it was considered unsafe to further increase the load. This load of 6 tons per sq. ft. was allowed to remain for five days before removal.

Frequent examinations were made to ascertain if the soil was rising in the bottom of the pit, but no such movement was observed. While making such an observation, after the load of 6 tons per sq. ft. had been reached, a loud cracking was heard and, remembering the nearly 18 tons of earth overhead, a hurried exit was made from the pit. Nothing happened, but this cracking noise led to an examination of the superstructure and it was

discovered that the 6-in. by 6-in. floor timbers had crushed about $\frac{1}{4}$ to $\frac{3}{8}$ in. directly over the upright posts, so that this and probably a small additional amount should be subtracted from the total settlement.

The soil at the points of testing was as follows: Test 1, at Massachusetts Avenue and Pearl Street, fine sand with enough clay to hold it together. Test 2, as described above, and Test 3, at Main Street nearly opposite Cherry Street, soft blue clay.

A settlement of $\frac{1}{2}$ in. was obtained with a load per sq. ft. in Test 1 of about 1 100 lbs., in Test 2 of 3 000 lbs., and in Test 3 of 7 000 lbs. A settlement of 1 in. was obtained with a load per sq. ft. in Test 1 of 10 300 lbs., in Test 2 of 6 000 lbs., and in Test 3 of 10 000 lbs. A settlement of 2 ins. was obtained with a load per sq. ft. in Test 1 of 17 000 lbs., in Test 2 of 11 000 lbs., and in Test 3 of 14 000 lbs.

These tests were made in September, October and November of 1906, under the direction of the late George A. Kimball, then chief engineer of Elevated and Subway Construction, and Mr. F. B. Edwards, division engineer. The writer had field charge of these tests and the previously made wash borings.

CHAS. T. MAIN (*by letter*). — We are indebted to Mr. Worcester for his very able and important paper.

I desire to say a few words regarding the conclusions which he has reached and recommendations made, and to add something concerning the work on the foundations for the new buildings of the Massachusetts Institute of Technology, which are now under construction on the new site in Cambridge.

Too much stress cannot be placed on the necessity of obtaining as full knowledge as possible of the conditions of soil or ledge underlying a proposed structure. I decided some time ago that I would not design and build any structure of importance without obtaining sufficient knowledge by borings, or preferably by test pits, if possible, to be sure that the foundations are properly designed to prevent settlement or failure, and that no money is spent in making them unnecessarily costly.

There have come to my notice many instances where this has not been done and where great expense has been incurred in trying to make things right afterwards, and many instances

where insufficient or lack of explorations have been the cause of too low estimates of cost.

I believe that the cost of such explorations is always justified and has often saved many times the amount later on in construction.

Explorations in Boston should include borings carried to bedrock if possible and the taking of dry samples of the soil every few feet in depth. The samples should be examined as soon as taken, as moisture evaporates and the character of samples changes rapidly.

(*a*) A record should be made of water levels.

(*b*) Test piles should be driven, keeping careful records.

(*c*) Piles should be tested by loading until marked settlement takes place, and careful readings made before and after each increment of load, loads being allowed to rest at least twenty-four hours after each increment, if possible.

(*d*) All test piles should be pulled, whether load tested or not, to determine their condition and suitability for the work.

There can be no exception to the importance of supporting all parts of the structure on a stratum of soil below the silt and peat.

There can be no doubt of the necessity of determining the maximum and minimum levels of the ground water.

The most of my work has had to do with buildings used for manufacturing purposes, which are subject to more or less vibration, and very few have been in the limits of the city of Boston. Because of the effect of vibration and the observance of what happened in a weaving mill in the earlier part of my experience, I have been very conservative regarding the loads on soils, and many years ago decided on the following:

Soft clay — One ton per sq. ft.

Compact sand and gravel — One to two tons per sq. ft.

Hard pan — Two to three tons and sometimes, under favorable conditions, four tons per sq. ft.

Except on soft clay I have increased these loads somewhat in later years, with more accurate knowledge of the conditions of the soil, and under favorable conditions with reference to the occupancy of the buildings.

In most of my work the loads on the footings are naturally rather low, and I have no special difficulty in keeping them down.

Supporting Power of Piles.

The results obtained so far on the new site of the Institute of Technology show that piles which have been properly driven, i. e., not broomed or broken, have a bearing capacity under the test loads slightly in excess of that indicated by the *Engineering News* formula, but those which have brought up hard and have been crippled have shown a very much less capacity under test load than was indicated by the formula.

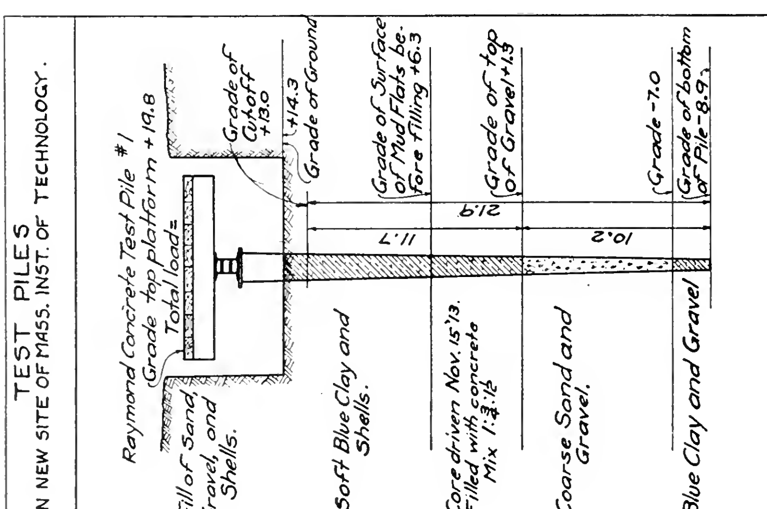
Piling at Massachusetts Institute of Technology Site in Cambridge.

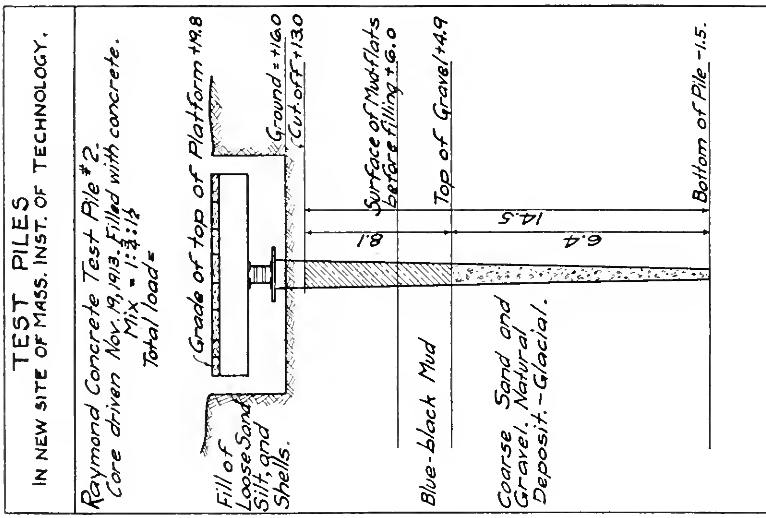
Tests and observation show plainly that spruce piles, without iron points, should be used cautiously in the Boston Basin, owing to the fact that the blue clay is often overlaid with a hard crust of gravel or sand. Reports of old piles which have been pulled in various parts of the city and found badly broomed and broken, as well as the numerous tests made at site of the Institute of Technology, show plainly that spruce is not suitable for anything but easy driving into loose sand or soft clay.

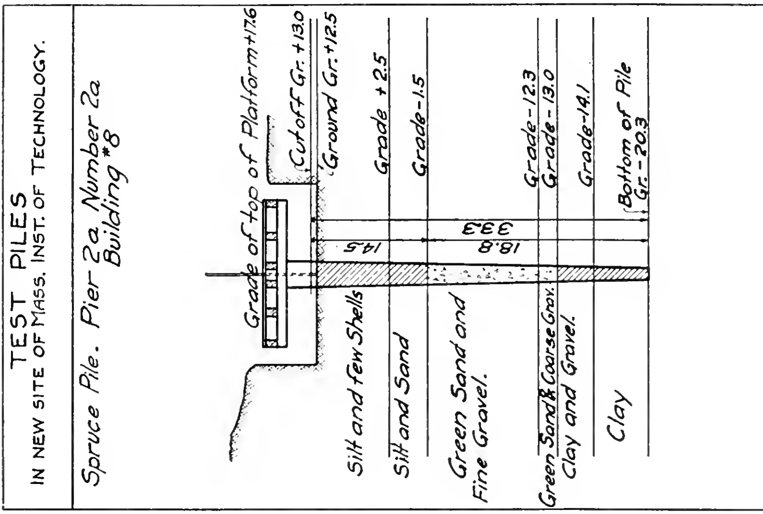
Piles broomed and broken near their points, but which are deeply embedded, may have a good bearing power from friction alone, but broken and broomed piles having no frictional support to depend upon will settle badly and may fail under ordinary loads.

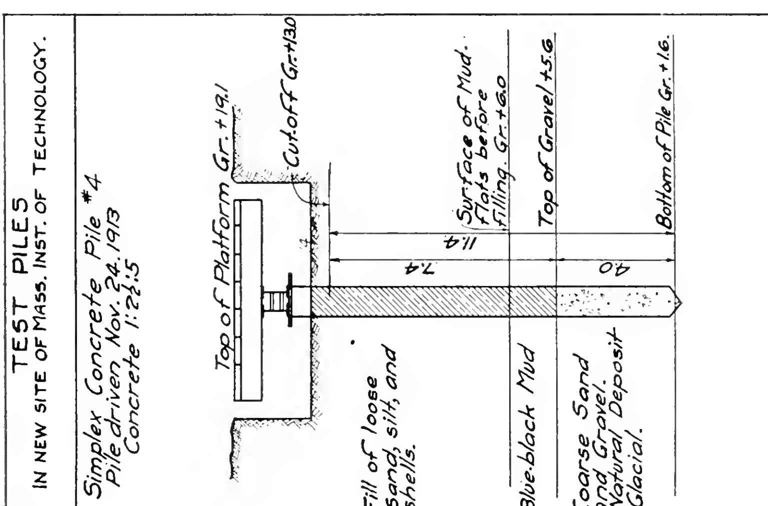
The large number of piles tested show plainly that while the spruce piles failed to penetrate the hard crust, brooming and generally breaking, oak piles not having iron points will penetrate the hard ground and come practically to a standstill without material injury. Any wood pile which is to depend largely upon point bearing for its value should be oak or southern pine.

An interesting point is brought out by a study of the driving and testing records of some of the piles. These piles generally pass through a fairly hard fill of blue-black silty mud and shells before reaching the harder sand stratum in which they get most of their support. This fill gives considerable resistance to

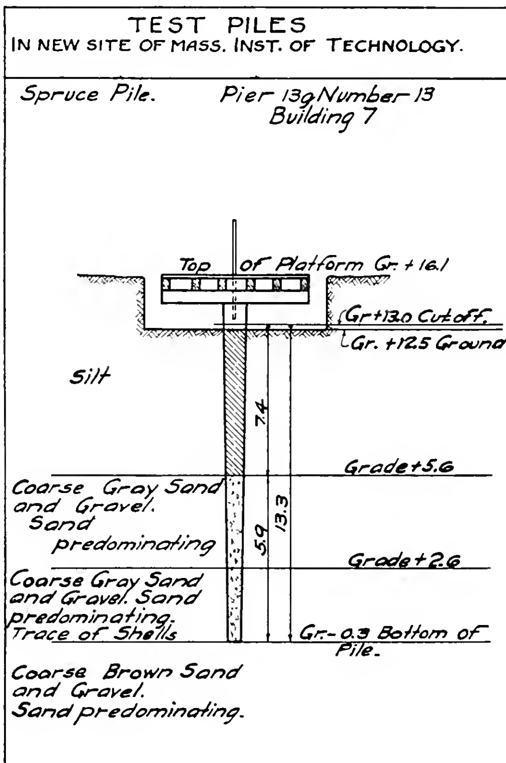

TEST PILES
IN NEW SITE OF MASS. INST. OF TECHNOLOGY.
Raymond Concrete Test Pile #1
Grade top platform + 19.8
Total load =
Fill of Sand, Gravel, and Shells.
Grade of Cutoff +13.0
+14.3 Grade of Ground
Soft Blue Clay and Shells.
Grade of Surface of Mud Flats before filling +6.3
Core driven Nov. 15 '13. Filled with concrete Mix 1:4:1½
11.7
21.9
Grade of top of Gravel +1.5
Coarse Sand and Gravel.
10.2
Grade -7.0
Grade of bottom of Pile -8.9
Blue Clay and Gravel


TEST PILES
IN NEW SITE OF MASS. INST. OF TECHNOLOGY.
Raymond Concrete Test Pile #2.
Core driven Nov. 19, 1913. Filled with concrete.
Mix = 1:4:1½
Total load =
Grade of top of Platform +19.8
Fill of Loose Sand, Silt, and Shells.
Ground = +16.0
Cut-off +13.0
Surface of Mud flats before filling +6.0
8.1
14.5
Blue-black Mud
Top of Gravel +4.9
6.4
Coarse Sand and Gravel. Natural Deposit. - Glacial.
Bottom of Pile -1.5.


TEST PILES
IN NEW SITE OF MASS. INST. OF TECHNOLOGY.
Spruce Pile. Pier 2a. Number 2a
Building #8
Grade of top of Platform +17.6
Cutoff Gr. +13.0
Ground Gr. +12.5
Grade +2.5
Grade -1.5
Grade -12.3
Grade -13.0
Grade -14.1
Bottom of Pile Gr. -20.3
14.5
18.8
33.3
Silt and few Shells
Silt and Sand
Green Sand and Fine Gravel.
Green Sand & Coarse Grav.
Clay and Gravel.
Clay


TEST PILES
IN NEW SITE OF MASS. INST. OF TECHNOLOGY.
Simplex Concrete Pile #4
Pile driven Nov. 24. 1913
Concrete 1:2½:5
Top of Platform Gr. +19.1
Cut-off Gr. +13.0
Surface of Mud. Flats before filling. Gr. +6.0
Top of Gravel +5.6
Bottom of Pile Gr. +1.6.
11.4
7.4
4.0
Fill of loose sand, silt, and shells.
Blue-black Mud
Coarse Sand and Gravel. Natural Deposit Glacial.

driving, and soon after the pile reaches the sand, it would generally appear, by the small penetrations under the hammer, that a theoretically satisfactory bearing power has been reached. This is not practically acceptable, however, as the fill is unreliable and subject to large future settlement owing to decomposi-



tion, etc., and should not be depended upon for permanent support, even if it appears to give temporary support, therefore the piles are driven into the hard sand stratum to a depth that will give a satisfactory support to them from that material alone. This is also necessary, in order to give stiffness to the structures against vibrations, especially where the fill is soft.

As noted before, most of the test piles, under actual loading test, could be allowed a slightly higher value than the *Engineering News* formula gave them, provided a very small initial settlement is allowed as not detrimental. If a settlement of $\frac{1}{4}$ in. is assumed as maximum, they have a factor of safety of 2 to 3, the piles having a deeper embedment as a rule showing the larger safety factor.

As the hard sand or gravel crust in the Boston Basin is often found over a deep soft underlying clay, it will reduce the possibility of settlement in those structures, which are to be supported upon the crust, if the piling or foundations are well spread so as to avoid concentrations of loads.

If the bearing stratum were not so far down as to make excavation in the fill, silt and water so expensive, the best thing to do would be to rest the concrete foundation directly on the hard stratum. This being out of the question, the next best thing seems to be to spread the weight over as much area as possible by driving a large number of wooden piles. Concentration of loads in a much smaller number of places spaced much farther apart would seem to be the least desirable method with a stratum of hard material of small thickness over a soft clay bed.

Professor William O. Crosby has made a report on the geological condition at the Massachusetts Institute Technology site, which is included as a part of the discussion.

Records of Other Borings and Tests.

South Boston. South Cove District — Old Colony Ave., Earl St., Damrell St. Two sets of borings.

Black soft peat found in layer varying from 2 to 7 ft. in thickness, having no marked inclination, top at about grade 8.5 and bottom at about an average grade of 3.6. Under this peat is found water-bearing sand, and this lies on hard yellow clay generally, with hard blue clay under the yellow. Then is found a soft blue clay, of unknown thickness, high parts at about —9.5 and dropping to —17 in a westerly direction.

It cannot be said that these borings show any marked subsidence of the sub-soil in recent times, as the peat is probably near its original location.

Tests of Piles in Site of New Massachusetts Institute of Technology Buildings.

Identity.	Character.	Total Length in Ground. (Feet.)	Length in Sand or Gravel. (Feet.)	Tip Diameter in Inches.	Weight of Hammer in Pounds.	Fall of Hammer in Feet.	Penetration, Last Blow, in Inches.	Test Load. (Lbs.)	Settlement. (Inches.)
2a	Spruce	32.8	16.6	$5\frac{1}{2}$	2 150	10	2	8 990	0
2a								13 760	$\frac{3}{64}$
8								20 030	$\frac{1}{16}$
. .								28 210	$\frac{5}{64}$
. .								34 200	$\frac{11}{64}$
. .								40 040	$\frac{11}{64}$
. .								45 898	$\frac{19}{64}$
. .								51 000	$\frac{19}{64}$
. .								58 070	$\frac{19}{64}$
. .								62 360	$\frac{19}{64}$
13g	Spruce	12.8	5.8	6	2 300	10	$2\frac{1}{8}$	6 570	0
13								11 860	$\frac{1}{32}$
7								21 300	$\frac{5}{32}$
								26 480	$\frac{5}{32}$
								32 423	$\frac{5}{16}$
								37 560	$\frac{3}{8}$
								42 960	$\frac{3}{8}$
1	Raymond concrete	23.2	10.2	8	No. 1 Vulcan. Weight of moving parts, 5 000	2.25	5 blows per inch	41 050	0
								46 070	$\frac{1}{16}$
								61 810	$\frac{1}{16}$
	Near No. 14 wood pile given by Mr. Worcester.							81 840	$\frac{5}{64}$
								86 710	$\frac{3}{32}$
								90 890	$\frac{1}{8}$
								100 330	$\frac{5}{32}$
								125 340	$\frac{3}{16}$
			(Pile	did	not fail)			144 770	$\frac{1}{4}$
								171 750	$\frac{11}{32}$
								182 120	$\frac{13}{32}$
2	Raymond concrete	17.5	6.4	8	5 000 No. 1 Vulcan	2.25	4 blows per inch	29 650	0
								44 420	$\frac{1}{16}$
								59 360	$\frac{1}{8}$
								110 630	$\frac{3}{16}$
								122 280	$\frac{1}{4}$
			(Pile	did	not fail)			126 700	$\frac{5}{16}$
								131 610	$\frac{3}{8}$
								158 104	$\frac{13}{32}$
								169 980	$\frac{35}{64}$
								175 870	$\frac{19}{32}$
4	Simplex concrete	15.6	4.0	16	3 300	12	$\frac{1}{4}$	42 490	$\frac{1}{64}$
								61 280	$\frac{1}{8}$
								85 800	$\frac{3}{16}$
								95 910	$\frac{3}{16}$
			(Pile	did	not fail)			133 790	$\frac{3}{16}$
								153 810	$\frac{1}{4}$
								177 020	$\frac{9}{32}$
								187 270	$\frac{11}{32}$
								192 270	$\frac{7}{16}$

Ground water level not recorded. Concrete piles used in two buildings.

CHARLESTOWN. Rutherford Ave. and Thorndike St.

Borings show the usual fill, mud, peat and sand mixed, loose sand and hard pan or hard packed gravel and rocks. Ground water is at about grade 7.

This location is about on the original shore line of the district, as the peat thins out to practically nothing at the northeasterly part of the lot.

The general inclination of the gravel, sand and peat is downward to the south.

Buildings in this vicinity are generally low and rest on the fill overlaying the mud and peat, consequently all heavily loaded buildings show marked settlements and are vibrated by every heavy team passing on Rutherford Ave.

The gravel or hard pan found under this site appeared to be very thick and was not wholly penetrated by our borings.

REPORT ON THE NEW SITE OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

BY W. O. CROSBY.

ORIGINAL TOPOGRAPHIC RELATIONS.

The new site, like the old site, is made land, reclaimed by human agency from the estuary of the Charles. The charts, alike of 1859 and 1887, show the new site as wholly included in the expanse of mud flats on the north or Cambridge side of the estuary, barely touched by bordering salt marsh at one point on the north, and by Whittemore Point, a low ridge or spit of glacial gravel, on the west, near the end of Harvard Bridge. The salt marsh tends, in general, to encroach upon the mud flat, and thus, eventually, a layer of peat is spread over the silt. Alternations of silt and peat in different parts of the Back Bay district and of Boston Harbor, extending to depths of 15 to 30 ft., testify to repeated oscillations of level accompanying a general slow subsidence of the coast.

The fact that no peat was found in any of the borings on the new site, a fact of considerable practical importance, shows con-

clusively that this has been a water area, at high tide (mud flat) if not at low tide (open channel), during all the latter part, at least, of post-glacial time. The older maps and charts represent several salt-water creeks or tidal channels as issuing from the marsh and uniting in the northern part of the new site to form a main channel, which crossed the line of the Esplanade near the southeast angle of the site on its way to join the main channel of the estuary. The head branches of these creeks and the salt marsh through which they meandered were effaced at an early date in the development of this part of Cambridge; but the new site of the Institute remained essentially unchanged until the building, in the early nineties, of the retaining wall of the Esplanade and the filling of the area thus enclosed with silt and sand pumped from the bed of the river.

Sources of Information.

To determine the character, thickness and succession of the substrata, including both the bedrock and the over-burden of unconsolidated materials, twenty-two deep borings have been made on the new site. These were systematically distributed, with a view to covering somewhat uniformly the entire tract, as shown on the boring plan and sections. Borings 2 and 20 were subsequently confirmed by test pits to depths of 19 and 26 ft. respectively. Three borings, also, have been made to the northward, at varying distances, beyond the limits of the new site, with a view to determining the probable causes of noteworthy settlements of various structures on the lowlands of Cambridgeport. A still broader and more comprehensive knowledge of the geological conditions on the new site has been made possible by a study of the very numerous borings that have been made in the surrounding territory in connection with the construction of the Harvard and Cambridge bridges, the Charles River Dam (and the marginal conduits of the Charles River Basin), and the Boston and Cambridge subways, and for many lesser undertakings and private interests, including a considerable number of deep wells. Back of all these special sources of information come the general conclusions in regard to

the geologic structure derived from a study of the ledges and drift deposits of a large part of the Boston Basin.

The Bedrock.

Of the twenty-two borings on the new site, ten reached the bedrock at depths of 120 to 135 ft., and penetrated it for varying distances, the maximum penetration being about 61 ft., in boring 9, which reached the extreme depth, for this series, of 192 ft.

The bedrock is, in all the borings which have reached it, a light gray, banded or thin bedded slate, resembling much more closely the slate ledges of Brighton and Newton than of Somerville. The cores show prevalent high dips (30 degrees to nearly or quite vertical); and, what is more important, they also show the slate to be extensively and deeply decomposed. In fact, the slate is, in large part, rotted to a whitish and more or less plastic clay; and close observation is necessary to determine the line between the drift and the bedrock. Under these conditions, naturally, only a very small percentage of core was saved, mainly in small pieces; and these must be supposed to represent only the more solid parts of the ledge. The great depth to which this decay of the slate has extended is rather surprising; and even in the bottom of boring 9, 61 ft. below the surface of the ledge, the slate is far from sound.

This deep decay of the bedrock is unquestionably local, and it is best explained as dating from preglacial times and as having survived glacial erosion in consequence of its occurrence in a sheltered position relatively to the surrounding bedrock areas, a deep, narrow valley transverse to the glacial movement being the most obvious suggestion. The borings afford proof of the existence of such a valley, trending southwesterly from the slate ledges of Somerville and Cambridge to join the still deeper buried valley of the preglacial Charles, the course of which is southeasterly from Watertown across the Back Bay and South End districts of Boston to Dorchester Bay. It follows, then, that beneath the new site of the Institute the surface of the slate bedrock is quite certainly deeper and less sound than beneath the territory to the north and south — Cambridge and Boston.

Although it would not, probably, be impossible to sink concrete piles to the bedrock, the expense of doing so would be prohibitory; and it is, fortunately, quite unnecessary to resort to this costly expedient to secure a satisfactory foundation for any structure which it is proposed to erect on the new site. We need not, therefore, regret that the surface of the bedrock is not so sound and solid as would be desirable if the stability of the projected structures depended upon it. Its depth completely eliminates the bedrock as a factor in the problem of providing a stable and enduring material foundation for the new Institute.

The Over-Burden.

The unconsolidated materials overlying the bedrock, include, in succession; (1) the bowlder clay or ground moraine of the great ice sheet; (2) the blue clay, deposited in standing water (glacial lake) along the receding margin of the ice sheet; (3) the glacial gravel deposited, delta-fashion, by streams tributary to the glacial lake; (4) the silt deposited by the river and tidal currents during post-glacial time; (5) the peat formed on the marshes simultaneously with the silt and frequently interstratified with the latter; (6) the artificial filling, bringing the surface to grade and converting mud flats to dry land. The relative thickness and general structural relations of these several formations are clearly exhibited, for the new site, by the boring sections.

. . . .

Summary of Foundation Conditions.

The bedrock (chiefly slate) is too deep to be seriously considered. Furthermore, it is deeply rotted, and if it were accessible it would probably require extensive excavation.

The bowlder clay, comparable with the bedrock in stability, is also at an impracticable depth.

The great bed of blue clay overlying the bowlder clay is undoubtedly more firm and stable than might be inferred from the moist samples furnished by the drill. This formation, reinforced by piles, has been the main reliance for deep foundations,

or the foundations of important structures, throughout a large part of the lowland areas of the Metropolitan District.

The glacial gravel (and sand) covers the blue clay over almost the entire area of the new site, and it is thickest and nearest the surface over that part of the site on which, chiefly, buildings are to be erected in the near future. The value of this formation for foundation purposes is shown not only by the resistance which it offers to piles, but also by its efficiency in distributing the load which must ultimately be borne by the blue clay. It is, in this respect, somewhat comparable to a bed of concrete spread over the surface of the blue clay. It should be, for the new site, the main reliance for foundations. No attempt should be made to excavate it, nor, in general, to drive piles through it; but the structures should, instead, rest upon it, either directly or through the medium of piles.

The silt is on no part of the new site so deep as to make it a necessary factor of the foundations, except in the sense that it may be excavated to permit placing the foundations of structures directly upon the glacial gravel. In other words, it affects the problem of a safe and satisfactory foundation only in a negative way.

The peat, so generally interstratified with the silt in surrounding districts, is, fortunately, conspicuous by its absence on the new site and is to be taken into account only in helping to explain the subsidence of structures in the adjacent territory, which is very generally underlain by peat.

Comparison of the New Site with the Old Site.

This comparison is decidedly reassuring as to the solidity and permanent stability of the new site, for the advantage or superiority is with the new site in every particular; and yet the old site, during a half century of occupation, has proved very satisfactory, except, perhaps, in the transmission to the buildings of the vibrations due to street traffic. The buildings have not settled appreciably, and certainly they have not settled differentially to such a degree as to involve cracking of the walls or other noteworthy injury. So far as known, the same is true of surrounding structures, some of which are of a very massive

character, except for a slight differential settling of the Public Library and of the New Old South Church, the tower of the latter structure having settled so that it has a considerable lean from the vertical.

To particularize geologically; according to the best information obtainable from deep wells, the depth to the slate bedrock is greater, probably 30 or 40 ft. greater, for the old than for the new site; the depth of the bowlder clay and the thickness of the blue clay are correspondingly greater for the old site; the glacial gravel (and sand) covering the blue clay on the new site is wholly wanting on the old site; the silt is thickest on the old site; and in the lower part of the silt on the old site are one or more thick beds of peat, a specially undesirable feature which is wholly wanting on the new site.

The great or decisive advantages of the new site are the presence of the glacial gravel and the absence of the peat; and in view of the fact that the old site has proved reasonably satisfactory without these advantages, we are certainly justified in regarding the new site as virtually above suspicion, the more especially since, as will be shown in the next section, the settlements which have been noted in the vicinity of the new site are clearly due to shallow foundations, the presence of peat, or to other causes which are and will be non-existent on the new site.

Settlement of Buildings and Other Structures in the Vicinity of the New Site.

The appended list * of fairly well-determined instances of settlement in the vicinity of the new site seems to show that settlement is a more or less general fact, and a fact demanding careful consideration and explanation. The principal causes of settlement have been noted, and it remains to show their applicability to the concrete examples. A large majority of the observed settlements are referable to four linear series, as follows:

Charles River Parkway, south of the new site.
North Metropolitan Sewer, north of the new site.

* This list is omitted, as the settlement of this region has been fully indicated elsewhere in this discussion.— Editor.

Massachusetts Ave., west of the site.
Main St., east of the new site.

Since the series completely surround the new site, the conclusion appears unavoidable that it, too, or at least structures placed upon it, must be subject to settlement; and this, doubtless, would prove to be the case were as little care exercised in the planting of structures on the new site as on the circumjacent territory.

It remains now to consider briefly the settlements of the several series with a view to determining the probable causes, the extent to which, if at all, these causes are inherent, in the new site and the appropriate remedies.

Charles River Parkway (Esplanade). — The observations of this series were made, not on the seawall, but along the inner margin of the Parkway. The seawall rests, not upon piles, as one would naturally expect, but directly upon the mud and silt of the original bottom of the estuary; while the parkway itself rests upon the made land behind the wall, the filling of silt upon silt, certainly not an ideal basis, even for a roadway. Under these conditions it is not surprising that both parkway and wall should have settled, but rather that they should have settled so little.

The parkway was finished to grade 21 in 1897; and no subsequent determinations of levels were made until 1908, when the results shown in the table were obtained, the total settlements ranging from .07 to .70 ft., equivalent to .0064 to .064 ft. per year. A uniform annual rate of settlement at each point is, however, extremely improbable. It is practically certain that the rate was relatively rapid at first, when the filling was but slightly compacted or settled, becoming gradually slower and finally almost stationary. The annual rates at the present time must be distinctly less than the mean annual rates given in the table, except perhaps at the corner of Ames St. and the southeast corner of the new site, where a second determination in 1912 showed a substantial continuance of the mean rate from 1897 to 1908. This is also the point of maximum movement, the total settlement being nearly double the next highest total

and much more than double the mean total. Evidently, exceptional conditions must exist here, and what these exceptional conditions probably are becomes apparent when we note that this point is on the most probable course of the tidal channel or creek which we have seen must have flowed southeasterly from the northern central part of the new site. Clearly, both the original silt and the filling must have exceptional thickness here; and hence it is not surprising that settlement of the surface should still be active, but that it will so continue is extremely improbable, the probability being, rather, that it has already begun to slow down and that it will, virtually, cease in the near future.

That the observed settlements of the parkway are due much more to the yielding of the filling than of the original deposit on which it rests is indicated by the statement of the city engineer of Cambridge to the effect that the retaining wall of the parkway (seawall), which we have noted as built upon the original deposit, but which, of course, cannot rest upon the filling introduced subsequent to its construction, has maintained almost its original level, having settled in all possibly one inch. He excepts, however, the point at the southeast corner of the new site, opposite the end of Ames St., where the wall crosses the old tidal channel. An apparent settlement of 6 ins. has been noted here, or about one half as much as for the corresponding point on the parkway. It appears, then, that the wall, with a decidedly greater weight per square foot than the material beneath the parkway, has proved the more stable, simply because it consists of unyielding granite resting upon original and relatively compacted deposits, while the material beneath the roadway is filling which has been, and is yet to some degree, uncompacted.

The wall, of course, and not the parkway, best exemplifies the conditions that will obtain on the new site, for the filling, it may be assumed, will not be a factor in the foundations of the proposed buildings, the foundations being carried either directly by excavation or by piles through both the fill and the silt to the glacial gravel. When we consider that the foundations will thus rest upon the glacial gravel, while the retaining wall rests upon silt and blue clay, with little or no gravel intervening,

we cannot doubt that the former will prove far more solid and stable than the latter, although the behavior of the latter (the wall) appeals to the engineer as, on the whole, highly satisfactory.

North Metropolitan Sewer. — This heavy masonry structure, dating from 1892, was built in the silt, with its base at or near the low tide level. The minimum settlements of the sewer in Cambridgeport are in the vicinity of Albany and Franklin streets, where it must rest upon or near the glacial gravel, and east of Main St., where the bowlder clay must approach the surface. In the vicinity of Massachusetts Ave., and between the avenue and Main St., the sewer crosses territory known to be underlain by peat; and it is legitimate inference from the official reports on the construction of this sewer that there is more or less peat below this section of the sewer. Peat, therefore, may be regarded as a probable cause of the settlement of the sewer. The reports state, also, that the sewer rests, in part, upon fine sand (probably glacial); and Mr. Charles R. Gow suggests that through the action of the pump used to drain the excavation during the construction of the sewer some of this fine sand was drawn through the open joints of the underdrain, thus undermining the sewer and permitting its subsequent settlement. This appears very probable and may be set down as a second cause of the observed settlements. A third cause is found in the fact that the maximum settlements, near Massachusetts Ave. and near the junction of Albany and Portland streets, coincide with the positions of the creek channels coursing through the ancient salt marsh. It appears, then, that even the extreme settlement of 2.3 ft. (0.1127 annually) directly north of the new site, on Albany St., may be fully accounted for without impeaching the foundation conditions of the new site.

Massachusetts Avenue. — It is needless to go into details here. The examples of settlement speak for themselves in the tabulated list. With rare exceptions, piles are wanting and the buildings rest, with shallow foundations, upon fill, silt, quicksand or peat; or, as in the case of the Metropolitan Storage Warehouse, upon the exceptionally deep filling of ancient creek channels. Riverbank Court, Seymour Apartments and the Armory rest upon the glacial gravel, and in their freedom

from settlement we have a plain indication of what may be expected on the new site.

Main Street. — This section, also, may be disposed of very summarily. The settlements are either very slight or the structures rest without adequate foundations on yielding materials, — fill, silt, peat or quicksand. All the observed settlements of any importance might have been predicted. In several instances the settlements are too slight to require explanation.

Miscellaneous Series. — The miscellaneous group of settlements east of Main St. are too slight to require explanation, with one exception, and in this case the conditions are not known.

SETTLEMENT TESTS ON THE NEW SITE.*

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Respectfully submitted,

(Signed) W. O. CROSBY.

FRANK H. CARTER (*by letter*). — The Society is to be congratulated upon having a member who is willing to devote so much of his time to the preparation of so valuable a paper.

As a matter of record, the writer desires to present, as a part of the discussion, additional data concerning the subsidence of part of Cambridge. That a large part of Cambridge has been undergoing a progressive settlement has been definitely known since 1897, when the writer was engaged in making an investigation of facts regarding the back flooding of certain sewers in the low area of Cambridge. Previous to that time, there had been trouble with some of the benches near Lafayette Square, but the difficulty had been thought to be local only. Under the direction of Mr. L. M. Hastings, city engineer of Cambridge, the writer ran levels through practically all the streets in the sunken district. Elevations were taken on bench marks, curbs, tracks, manholes and catch basins, as well as on every other point upon which levels might have been taken in years past, for comparison with the old elevations. The area of settlement

* These tests are omitted here, as they were described by Mr. Gow in his discussion, p. 180.

proved to be about one square mile in extent with a maximum settlement of about two feet in the center analogous to a large, shallow saucer, with zero settlement at the perimeter.

Some fifty miles of bench levels were run to tie up with benches of undoubted permanency, some of which were situated two or more miles away on the solid hilly formation in the western part of the city near the Harvard College Observatory, and others some two miles farther away near the Belmont town line.

Engineers from the Metropolitan Water and Sewerage Board corroborated the settlement, finding that the Metropolitan Sewer through Cambridge had gone down two feet at the maximum point.

When the surveys for the Boston Elevated Railway Company's extension to Cambridge were made in 1901, further information was obtained, which, when compared with the levels previously taken by the writer, showed a fairly uniform settlement of something over an inch a year at the maximum points. In succeeding years, 1906 and 1909, other parties from the Boston Elevated Railway Company have further corroborated the settlement, ascertaining that the rate of settlement is unabated and shows no promise of lessening.

Heavy structures on pile foundations, light wooden buildings, curbs, street railway tracks and sewers all go down at the same rate, viz., 1 to $1\frac{1}{4}$ ins. per year in the center of the settled district.

The writer's interest in this settlement was intensified when, as designing engineer of the Boston Elevated Ry. Co., with the late George A. Kimball, chief engineer, the author, Mr. Jos. R. Worcester, consulting engineer, and Mr. Chas. W. Mills, also consulting engineer, he designed the arch section of the Cambridge Main St. Subway in Main St., from Kendall Square to near Austin St.

Mr. Fred B. Edwards, division engineer of the Boston Elevated Ry. Co., under whose supervision the borings for the subway were made, devised a kind of geological profile interpreted from the wash borings. On a copy of this profile the writer plotted the various profiles of the surface of the street taken in 1869, 1897, 1901, 1906 and 1909, showing the progres-

sive settlement, as well as the proposed profile of the subway (shown in Fig. 2). Mr. Edwards stated that the sounding rod would sink several feet of its own weight in a number of places after passing through a kind of crust of harder clay which seemed to overlay the softer clay underneath. Artesian well

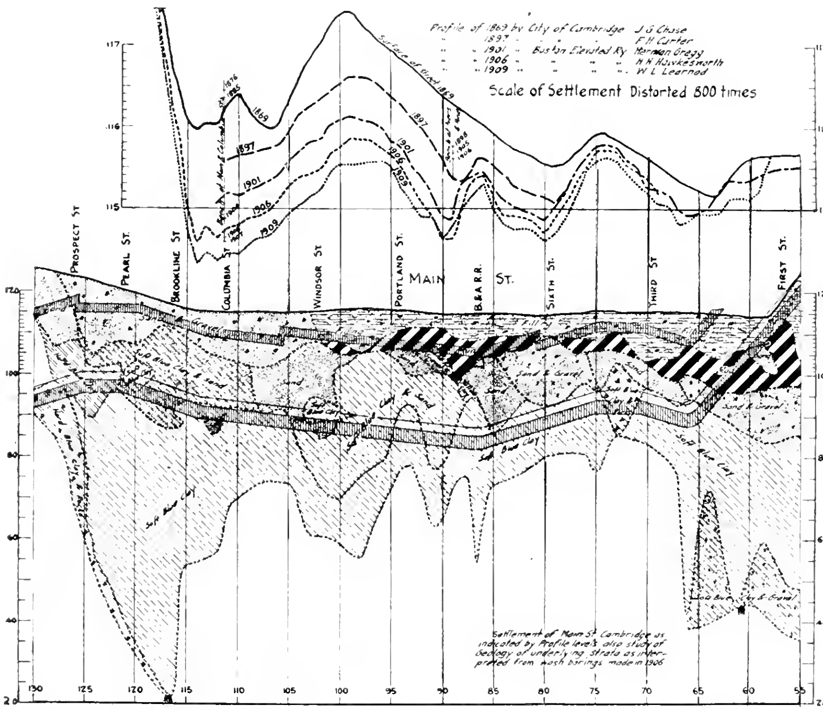

FIG. 2. PROFILE ALONG MAIN ST., CAMBRIDGE, SHOWING THE PROGRESSIVE SETTLEMENT FROM 1869 TO 1909, AND SUBSOIL STRATA FROM WASH BORINGS MADE IN 1906. GEOLOGICAL FORMATION CONFIRMED BY SUBWAY EXCAVATIONS.

Upper profiles are to vertical scale 800 times horizontal scale illustrating the settlement.
Main profile is to vertical scale 40 times horizontal scale.
Profile 1869 by City of Cambridge, J. G. Chase.
Profile 1897 by City of Cambridge, F. H. Carter.
Profile 1901 by Boston El. Ry., H. Gregg.
Profile 1906 by Boston El. Ry., H. H. Hawkesworth.
Profile 1909 by Boston El. Ry., W. L. Learned.

The location of the subway roof and invert is shown by the two parallel bands of shaded areas across the drawing, the bottom of the invert ranging from Elevation 85 to Elevation 95 approximately.

diggers reported the same experience in the vicinity of the subway borings.

With all this information at hand the writer's design of the invert for the subway previous to excavation provided for a uniform distribution of the weight of the loads from the side walls over the whole width of the subway which resulted in an invert of considerable thickness. The excavation for the subway revealed the actual character of the clay upon which the invert of the subway was to rest, and with the bearing power experiments made with test piles indicated without doubt that the "crust" of harder blue clay could be depended upon to support the subway side walls and invert without the uniform distribution which had been thought necessary before the clay bottom was exposed. The depth of invert was accordingly reduced about one half.

Fig. 1, page 194, is a map of the settled district. Fig. 2 is a profile through Main St., Cambridge, with a study of the geological strata as indicated by wash borings made in 1906. Bed rock has been sounded at a depth of from 90 to 100 ft. below the surface, with indications of a thick layer of very soft clay on top, though wash borings are not to be entirely depended upon, as has been revealed by the actual excavation for the subway proper. It was found that "soft blue clay" near the surface was a misnomer, when actual excavations for the subway were made, and that the crust of harder blue clay was thicker than had been judged from the wash borings. Soft clay may, however, exist down next the bedrock.

Above the main profile a greatly exaggerated set of profiles is given of the various lines of levels run by City Engineer Chase in 1869, on the establishment of a legally accepted grade; by the writer in 1897 at the time of the discovery of the settlement, and by Messrs. Herman Gregg, H. H. Hawkesworth and W. L. Learned, assistant engineers, Boston Elevated Railway Company.

Tables I and II list a typical set of observed settlements at different dates.

Most of the Cambridge Subway invert, which is from five to ten feet below mean low water, is laid in blue clay. A

TABLE I.

Elevations and Settlement of Bench-Marks in Cambridge.

(Compiled from City Engineer's Note Books.)

Date.	Main St. and Mass. Ave. Orne's Cor.	Main St. cor. Columbia St. Stone Bound.	Mass. Ave. Moller's Bldg.	Odd Fellows' Bldg., Mass. Ave. opp. Norfolk St.	School St. cor. Windsor St. School House.	Washington St. and Columbia St. Swedish Church.	Mason & Hamlin's, Broadway at Burleigh St.	Closes', Broadway and Windsor St.	Main St. and Albany, Ivers & Pond.	Metropolitan Storage Warehouse, Mass. Ave.	Harvard Bridge Abutment, Mass. Ave.	Reardon's Factory, Waverly St. and Talbot St.	Brookline St., cor. Pilgrim St.	Central Sq. Hydrant.
1876	......	21.324	......	......	......	......	......	......	......	......	......	......	......	......
1885	*21.284	21.228	......	......	......	......	......	......	......	......	......	......	......	......
1889	†21.084	......	......	......	......	......	......	......	......	......	26.033	22.547	......	......
1897	20.711	......	20.744	24.679	......	......	......	......	......	21.765	25.870	......	20.320	31.144
1898	......	......	......	......	19.712	......	19.198	21.971	20.637(?)	......	......	......	......	......
1899	......	......	20.621	......	......	......	......	......	......	......	......	......	20.365(?)	......
1900	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1901	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1902	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1903	......	......	......	......	......	......	......	......	......	21.118	......	......	20.382(?)	......
1904	19.876	19.771	20.187	24.243 24.210	19.320	......	......	......	......	21.056	25.876	......	......	31.140
1905	......	......	20.171	......	......	21.113	19.119	21.831	20.570(?)	21.047	...	22.550	......	......
1906	19.667 19.654	19.551	19.956	24.110	19.133 19.097	21.043	19.055	21.788	20.502(?)	20.843	......	22.460(?)	......	......
1907	19.593	19.485	19.894	24.069	19.086	21.062	......	......	......	20.847	25.800	......	......	......
Total	1.691	1.839	.850	.610	.626	.051	.143	.183	.135(?)	.918	.233	.087(?)	—.062(?)	.004
No. of years	22	31	10	9	9	2	8	8	8	10	18	17	6	7

Question mark (?) indicates doubtful measurements.

* 1901. † 1895.

TABLE II.

Comparison of Bench Elevations, Cambridge City Engineers' Levels and Boston Elevated Railway Company Levels.

Bench.	Elevations by City. City base.										Elevations by B. E. Ry. Co. City base.		
	Sept., '85.	March, '91.	March, '98.	Aug., '99.	Oct., '99.	March, '04.	Nov., '04.	March, '05.	March, '06.	April, '07.	Aug., '01.	June, '06.	Feb., '08.
Standard near Old City Hall	30.208	30.208	30.208	30.208	30.208	30.208	30.208	30.208	30.208	30.205		30.214	30.241
Hydrant spindle, Central Sq.						31.105	31.141		31.108	31.117		31.132	31.120
Bolt in Odd Fellows Hall Building			24.679	24.586		24.243	24.210		24.123	24.069			24.038
East end stone step, No. 545 Mass. Ave.							25.439		25.348				25.215
Southwest cor. step, No. 509 Mass. Ave.	25.236												
Stone bound at Orne's Corner	21.284	21.084							19.667	19.593			19.549
Stone bound cor. Main and Columbia Sts.						19.771			19.554	19.485			19.441
Bolt in Moller Building			20.744	20.621		20.171			19.956	19.894	20.425	19.994	19.844
Buttress entrance W. M. Church, Columbia St.									20.665				20.624
Bolt in Boardman School, Windsor St.			19.707	19.611	19.609	19.320			19.113	19.086			19.056
Bolt in building cor. Main and Portland Sts.				21.962					21.624				21.615
Stone bound cor. Main and Portland Sts.	21.488										21.031	20.804	20.715
Hydrant spindle cor. Main and Albany Sts.			22.847					22.271	19.571				*22.141
Bolt in Ivers & Pond Factory			20.637	20.534				20.672	20.502				

* Probably reset in the interval.

thin layer of sand underlies the subway invert on Main St. from Austin St. nearly to Massachusetts Ave., according to Mr. Robert B. Farwell, formerly division engineer for the Boston Elevated Railway on the construction of the Cambridge Main St. Subway, and further corroborated by the profile.

A copy of the profile showing the probable geological formation as deduced from the wash borings was in the hands of the construction engineers of the Cambridge Subway before and during construction. These engineers have since stated that this "wash boring" profile, shown in Fig. 2, was substantially confirmed in all but minor details by the subway excavations, for the depth made.

Mr. Farwell states that there was no evidence of any deposit of peat anywhere near Lafayette Square or in Massachusetts Ave. from the surface of the ground to the bottom of the subway excavation, much less on the invert. (Lafayette Square is one of the points of maximum settlement.) Prof. W. O. Crosby informs me that to his knowledge clay sometime overlies a deposit of peat.

Not one of the Cambridge Subway borings, however, gives any indication of a deposit of peat underlying the clay. It is well known that wash borings are not to be depended upon with any certainty, but it may reasonably be inferred that at least some of the borings would have indicated peat had such an underlying deposit existed.

There are profiles of all the streets in the sunken part of Cambridge on file in the City Engineer's office in Cambridge, substantial evidences of the extent of the settlement, showing both old elevations previous to the sinking, and the grades established in 1897, in conformity with the new elevations of the surface of the streets.

From the map (Fig. 1, page 194), it is reasonable to conclude that the subsidence of the Main St. District is a local phenomenon as compared with the slower one of much greater extent, referred to by John R. Freeman in his report on the Charles River Dam. There seems to be a general subsidence of the entire Boston territory, and probably of a large part of the North Atlantic coast, with reference to sea level. The report

presents this matter fully, as concerns the Boston region. The following paragraphs quoted from the appendix to that report, written in 1903, state the facts briefly:

" All of the territory in and about Boston is probably slowly sinking relatively to the level of the sea. Apparently this subsidence is at the rate of about one eighth of an inch per year, one inch in eight years, or a little more than a foot in each one hundred years.

" This is obviously a question of great importance in comparing ancient soundings with modern, and in considering the possible future shoaling of the harbor.

" The present datum plane to which all elevations are referred by the engineering department of the city of Boston, and which is commonly known as 'Boston Base,' probably coincided almost exactly in the year 1830 with mean low water at the Charlestown Navy Yard. Prior to the Miner levels of 1878 the Boston datum had always been supposed to be at mean low water, and was so marked on the plans made by the city up to 1878.

" In 1878 Boston Base was found to be about 0.64 ft. below mean low water as determined by the United States Coast Survey at some time just prior to 1870.

" To-day, after the lapse of seventy-two years, this same datum plane, as defined by numerous bench marks on solid ground, according to the best available determinations, is 0.79 ft. below mean low water.

" This comparison shows that the land now stands about 0.79 ft. lower relatively to the sea than it did about seventy-two years ago, and therefore shows that the land in Boston and vicinity is sinking at the rate of about one foot per hundred years.

" Making a similar comparison on the basis of mean sea level, instead of mean low water, we find the rate of change is 0.71 ft. in seventy-two years.

" This change affects a very large area, and a variety of independent proofs is offered.

" At this rate, the present grade of Atlantic Ave. near foot of State St. (15.0 Boston Base) will be awash by the spring tides of each month about two hundred and fifty years hence.

" The proofs of this subsidence in brief are:

"(1) The sills and floor of the masonry dry dock at the Charlestown Navy Yard now stand about 9 ins. (0.71 ft.) lower relatively to mean sea level than any did seventy-two years ago, while the dock stands at precisely the same level relatively to points on solid ground.

"(2) The comparison of sundry tide gages, ancient and modern, indicates progressive subsidence.

"(3) Many rocks about the edges of Massachusetts Bay are found to be from 1 to 2 ft. deeper below extreme low water now than they were about ninety years ago.

"(4) The extreme tides in great storms appear to show progress toward greater heights.

"(5) At many points about Boston tree trunks are found standing in salt marsh under conditions that prove a recent subsidence.

"I was led to investigate this matter by consideration of statements of Prof. W. O. Crosby regarding the geological causes which had formed Boston harbor, resulting in a submerged valley; and from my observation of the peculiar relation of the datum plane at present used by civil engineers on the Boston public works, known as 'Boston Base,' to the ancient datum plane of 'marsh level' and to 'mean low water,' and because of the unsatisfactory explanations offered as to why 'Boston Base' was established at the odd distance of 0.64 ft. below mean low water, I was led to investigate the old bench levels.

"I had for some years past been interested in the indication of comparatively recent subsidence found in the resemblance of some of our coastal indentations to ordinary valleys that had become submerged, and in studies as to the future water supply of Brooklyn (Report on New York Water Supply, 1889–90) I had occasion to review the proofs of recent subsidence offered by the State Geologist of New Jersey, and was therefore the more ready to follow out the indications of the present case."

The general subsidence which Mr. Freeman demonstrates has important bearing on elevations of harbor works, bridges, sewers and the like. On the other hand, the much more rapid local subsidence in Cambridge, above described, seriously affects the structural design and the grades of sewers, subways and other continuous underground structures crossing the district of movement.

C. T. FERNALD (*by letter*). — The careful and painstaking work and the important bearing which Mr. Worcester's paper will have on the design of foundations in and about Boston certainly entitled him to the thanks of the Society and of the engineers practicing in this community.

In my own experience I have found, however, one or two instances, possibly due to an error in judgment, where results have been at variance with the conclusions reached by Mr. Worcester.

Under the heading of "Summary of Recommendations," Item 1, Section B, — query is made "whether piles are likely to be an advantage, and if so, how long willt hey probably be?" My own answer to this would be, when in doubt use piles, as the correct answer to the above can only be determined when the bearing power of the soil is given its approximately safe value. As an instance, during 1911, in building the elevated structure connecting the Cambridge Bridge with the Beacon Hill Tunnel, the original soil, blue clay, on which the two most easterly piers supporting this structure were placed, was exposed. This blue clay might be classed as fairly hard, and the load it was to support on each pier amounted to 3.3 tons per sq. ft. One of them, however, the one toward the Charles River, began to settle shortly after its completion and continued to do so for nine months until it was 0.6 ft. below its original position. It was only after the footing of this pier had been increased in area from 231 sq. ft. to 522 sq. ft. and the load reduced to approximately $1\frac{1}{2}$ tons per sq. ft. that settlement ceased. The more easterly pier has never settled from the time it was built, yet the quality of the clay was apparently exactly the same.

Under Item 1, Section C, I think the conditions surrounding the building of a structure, or probably the sequence in which the work is done, have a great influence on its future stability. For instance, of the river piers of the Charles River Bridge, those which were built adjacent to the completed work of the Charles River Basin Commission have settled but very little, while whose which were built prior to the completion of filling the dam settled from 0.1 to 0.33 ft. and tipped toward the dam or fill in proportion to the depth of the fill. Owing largely to this settlement, work on the completion of the superstructure for the bridge was delayed until the dam itself was filled to its final grade. There is no doubt, I think, from a study of the conditions, that all of this movement was due to the compression of the soft clay underlying the stratum of gravel on which the

concrete foundations were placed and through which the supporting piles were driven into the clay. A further settlement of the piers took place when the superstructure was added, but it was comparatively uniform throughout. The tendency to tip toward the dam was not continued when this superstructure was added.

Under Item 3, in my judgment grade 8 is as high as it is safe to cut off piles in filled land which is near tide water. The older buildings on Lowell St. at the West End are supported on piles cut at grade 11. In cases where elevated foundations were built adjacent to these buildings some of the old piles were exposed and were found to be entirely rotted from the top down to about grade 8, at which elevation they were comparatively sound. In some cases we were forced to renew these piles above grade 8 to make the structure as safe as it was originally. At the old site of the Hendricks Club, corner of Causeway and Lowell Sts., piles cut at grade 8 supporting the old structure were found to be sound and were counted upon to assist in the support of the new structure recently erected there. On Beach St., just below Harrison Ave., adjacent to the elevated structure, the owner of a building claimed that the dangerous cracks and settlements were due to the construction of the elevated structure. An investigation of the foundations for this building, however, disclosed piles supporting the front and side walls cut at about grade 10.9, and their tops for a foot or more below this were entirely rotted away and of no value. Below this latter point, however, they gradually grew better so that at approximately grade 8.5 they were in fairly sound condition. In all of the above instances the piles were driven in filled land which at one time was under water. In my judgment it will not be safe to cut piles above this grade except possibly where they were near enough to tide water to be affected by the full range of the tide.

Under Item 4, from my experience noted under the heading of Item 1, I should be inclined to assume as the safe bearing power for medium blue clay, 3 tons, and for soft clay, running sand (confined), 2 tons.

Under Item 5, as to the supporting power of the piles, if we are prepared to accept the settlement of $\frac{1}{4}$ in., which I think is

reasonable in any structure, the modification in the *Engineering News* formula for the safe supporting power of the piles, as suggested by Mr. Worcester, is conservative. In January, 1900, while the Lincoln Power Station was under construction, tests were made of two piles 35 ft. and $29\frac{1}{2}$ ft. long respectively, which were driven into the stiff blue clay and sand, leaving 4 ft. above the ground. The total penetration was 23 ins. and 22 ins. respectively in the last ten blows with a 1 800 lb. hammer and a 31-ft. drop.

By the old *Engineering News* formula these piles were good for 16.9 tons, and by the modified formula they would be reckoned as good for 25.36 tons.

Load.	Settlement.	Load.	Settlement.
14.83 tons.	.003 ft.	16.13 tons.	.001 ft.
23.07 tons.	.01 ft. *	20.84 tons.	.025 ft.
33.30 tons.	.045 ft.	28.01 tons.	.051 ft. *
39.58 tons.	.055 ft. (failed).	28.73 tons.	.059 ft.
		30.48 tons.	.075 ft.
		33.06 tons.	.087 ft. (failed).

The above tabulation shows the settlement occurring as the added loads were applied, the failure being caused by the splitting of the pile above the ground, and it will be noted that the settlement in both of these piles for a loading approximating that calculated by Mr. Worcester's formula is very close to the $\frac{1}{4}$ in. reckoned.

HARRY E. SAWTELL (*by letter*). — Permit me to express admiration for Mr. Worcester's paper, and in presenting this discussion it is hoped that a little of value may be added to it.

Referring to five tests of piles recently made at the new site of the Massachusetts Institute of Technology, and given in Mr. Worcester's paper as numbers 10 to 14, it is noticed that the total length in the ground is given with no further information as to how much of the length is through fill and what part is in the harder glacial deposit. The writer thinks it will assist in gaining a more complete understanding of these tests if the amount of penetration into the firmer glacial deposit is given.

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* Approximates J. R. Worcester's formula.

	Total Length in Ground. Feet.	Length in Glacial Deposit. Feet.
No. 10	28.7	About 12.0
No. 11	32.08	About 17.0
No. 12	41.6	About 22.0
No. 13	26.7	About 14.0
No. 14	23.6	About 11.0

It will be seen that only about one half of the length of these piles rests in the reliable stratum. Before reaching it the piles passed through fill, mud, silt, etc., of a very unreliable character.

These facts will affect the showing made by these piles in Mr. Worcester's table wherein are found "coefficient lbs. per sq. ft.," as it appears to the writer better to use the actual lengths of embedment in the hard soil rather than the whole length, including a soft fill, silt, mud, etc.

The writer agrees with Mr. Worcester that the method of arriving at the value of piles by a surface coefficient is uncertain, not only because of the inability of determining at all times the length to consider, but also on account of variable character of the soil through which the pile may be driven.

Without question borings should be made to assist in ascertaining not only the depth and character of the firm subsoil, but also of the fill. It is the writer's belief that owing to the fact that the character and levels of the sub-strata change within a few feet in many localities in the Boston Basin, borings in a site should be made quite close together in order to be of full value.

This quick change of character and levels of strata has been particularly noticeable at the new Technology site, and has frequently necessitated using piles of as much as 25 ft. of difference in length within short distances. Under such conditions it should not be expected that anything more than approximate knowledge of the sub-soil would be gained with borings placed 200 to 300 ft. apart; 25 to 50 ft. would be better.

The danger of being mislead is great when driving piles through a hard fill into a desirable sub-soil, as the resulting formula load does not give true results but too high ones. Piles driven through hard fills are not ordinarily given much penetration into the good, firm soil under the fill, and consequently

have a small true value, and as most fills contain a large percentage of matter which will decompose, shrink in volume and settle, it will by friction on the pile surfaces add to their load and cause settlement. The above condition is a fact more frequently than it should be and emphasizes the necessity of full knowledge of the soil.

The writer wishes to call attention to the desirability of giving piles a deep embedment when driving into most kinds of soft sand or silt and sand containing water, as it has been noticed that, while a formula value may be obtained soon after penetrating the sand a few feet and which cannot seem to be raised by further driving, it is noticed, however, that those piles having the deeper penetration show the greater capacity and less settlement when tested by load. This undoubtedly is because when driving the pile the soil around it is agitated and kept in a more or less liquid state, offering a lessened resistance, but after coming to a state of rest the resistance increases very largely and the greater the length of pile, the greater the gain in value. Different authorities have spoken of this gain after the soil has been allowed to rest and become compacted, but such tests appear to have been in other sections of the country. It would be of value if we could get an idea of what it would be from tests for a typical Boston soil.

It is noticed that Mr. Main in his discussion speaks of pulling test piles for the purpose of determining their suitability for the proposed site, and further makes the statement that it had been found that spruce piles were suitable for soft driving only.

This is of importance, and will largely obviate the necessity of depending upon the contractor's judgment as to what are good and bad piles. The knowledge gained from borings and test piles pulled will enable the engineer to place pile foundations with a degree of surety impossible otherwise. Too many piling jobs are done based on the piling contractor's judgment rather than on an engineer's judgment.

Test piles which have been pulled at the Technology site have shown conclusively that when piles are to depend largely or wholly on point bearing in a hard stratum, spruce should not be used, for they break, deflect and break or broom to such an

extent as to be wholly unreliable. Spruce may, however, be used without danger in softer driving where dependence is placed on friction for its value.

Hard driving may be defined for wood piles having 6 ins. or smaller points as less than an average penetration of $1\frac{1}{2}$ ins. for the last three or four blows under a 2 300 lb. hammer at a 10 ft. drop, and soft driving would be secured when the penetration was greater than $1\frac{1}{2}$ ins. under the conditions as outlined above.

Regarding Mr. Worcester's proposed change in the *Engineering News* formula, the writer would regret to see it made, as he believes, first, that it would result in greater settlements under working loads; second, from long observation it is believed that a large part of the piles driven are, unlike test piles, seldom given the penetration required which now results in doing what Mr. Worcester would do by changing the formula; third, that an unknown percentage of spruce piles driven under the present conditions are unreliable, due to brooming and breakage; fourth, that as this construction is out of sight, a greater factor of safety should be obtained than for construction in sight which can be inspected; fifth, that the factor of safety obtained by the *Engineering News* formula is now relatively low when based on a reasonable settlement of the pile itself. This was brought out by Mr. Worcester in his paper.

In regard to Mr. Worcester's suggestions for safe bearing pressures on soil, the writer thinks that $2\frac{1}{2}$ tons per sq. ft. is excessive on "soft clay, running sand (confined)," owing to the difficulty of really getting a permanent confined condition in actual construction.

Having in mind Mr. Worcester's statement that he does not wish to continue the work of "Boston Foundations," and believing that it is a very important and valuable work to Boston and vicinity, the writer hopes that the Boston Society of Civil Engineers will appoint a committee to carry on the work and thus increase the knowledge of a subject very important to the city of Boston.

Lester W. Tucker (*by letter*). — Mr. Worcester's paper is most interesting and instructive to the engineers who have been

engaged in foundation construction in the city of Boston and vicinity. The writer is especially interested in the chapter on ground water level and wishes to add a personal experience on this.

After the leasing of the Fitchburg Railroad by the Boston & Maine Railroad in 1900, it was decided to remodel the old Fitchburg station, making it over into an office building, and the writer was in charge of the work.

In putting in some new foundations near the outside walls it was found that some of the piles under the walls of the station were badly rotted at the tops, and a careful examination of these foundations showed that the piles had originally been cut off at grade 10 and the stone foundations built directly on these piles. They were driven in two rows about 30 ins. on centers, staggered, except under the wide pilasters, where they were three rows instead of two. The piling was oak or chestnut, there being practically no soft wood piles under the building. The top 18 ins. of many of these piles was badly decayed, there being scarcely enough good piles left to support the walls. These piles had been driven in 1847 and so had been in place fifty-four years, with cut-off at practically mean high water. The filling around these piles was dump material and very porous, so that the piles were completely saturated at every high tide. A careful examination of the piles showed them to be in good condition at grade 7, and in reconstructing the foundations they were cut off at this elevation. This experience would seem to indicate that we are not warranted in using a cut-off grade much higher than grade 8, and it is the writer's opinion that Mr. Worcester's question whether grade 8 would not be a reasonably safe assumption for low ground water level is practically right for those parts of Boston which are near enough tide water to be affected by the rise and fall of the tide. It is the writer's belief that grade 9 or 10, which has been adopted for so many of the cut-offs in the vicinity of Boston, is high and that we are not warranted in using anything better than grade 8 for this cut-off.

Granville Johnson (*by letter*). — Mr. Worcester mentions certain cases where the water level varies from that naturally to be expected. I had some experience with a similar case

at the corner of Massachusetts Ave. and Windsor St., Cambridge, opposite the old bicycle track.

The building on the land was started in September, about two years ago. The grade of the Basin is, and was at that time, I believe, approximately grade 13.00, and at that time some parts of the land were at approximately grade 12, Cambridge base. The land was free from water. The grade of the top of the basement floor is 12.25. The floor is of reinforced concrete and is not waterproofed. In the spring some leaks developed at the joint between walls and floor, during and after fairly heavy rains. The joints were then waterproofed.

I believe there have been no leaks through the floor, which I should expect if there were a head of water upon it. The sewers sloped toward Boston. At the corner of Windsor St. and Massachusetts Ave. they are at grade 11.50. The foundations of the building rest on coarse gray sand from three to seven feet below grade 12. I have not been able to find from our records at just what grade the water level was when the excavations for the foundations were made. I believe, however, that it was below grade 11.

I agree heartily with Mr. Worcester in his recommendation as to the advisability of making borings. I have had a case recently in Worcester bearing on this. Test pits showed 7 ft. of miscellaneous filling and then coarse sand, apparently an excellent bearing material. Borings showed miscellaneous filling, then ten to twenty feet of sand, and then in places three to four feet of silt.

I believe Mr. Worcester's recommendation for the safe load on confined saturated sand to be lower than need be in many cases. I have found very fine sand to sustain a load of nine tons per sq. ft., with a settlement of not more than $\frac{1}{8}$ in under test.

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PAPERS AND DISCUSSIONS

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ADDRESS AT THE ANNUAL MEETING, MARCH 18, 1914.

REQUISITES FOR SUCCESS IN ENGINEERING.

By Frederic H. Fay, President, Boston Society of Civil Engineers.

The custom of presenting an annual address by the President, now common in all of the national and the larger local engineering societies, doubtless had its beginning in this country in the American Society of Civil Engineers, where originally the president was required to give a review of the progress of engineering during the preceding year. With the rapid development and tremendous broadening of the engineering field it became necessary to modify the custom, and instead of attempting to present a comprehensive survey of the advancement in engineering, the president found it necessary to confine himself to some particular engineering topic.

In what I have to say to-day you will find little that has not been said before, often in an abler way, but I wish to speak of some fundamental points which I believe should be constantly borne in mind by every engineer who seeks to advance the interests of himself and his profession. Particularly do I desire to speak to the younger members of the Society, who in due time will be called upon to take up the burdens and responsibilities now carried by their seniors, and who must in their turn become leaders of the profession.

The future of engineering is bright. Opportunities are expanding. The world is coming to expect and to demand a higher

standard of the engineer and of engineering. The younger members especially should be alive to the situation. They should foresee what the future has in store, and they should endeavor to so train themselves that they will be prepared to seize the opportunities as they are presented, and be fit to assume the greater responsibilities that are coming, and are bound to come, to engineers.

The Outlook.

The profession of engineering is the oldest of all professions, and dates from the earliest and most elementary civilization; but it is only within comparatively recent years that it has become recognized as a distinct profession, and we must still look to the future for that full recognition to which we engineers believe the profession is entitled. Upon no profession does the world depend so much for its advancement as upon the profession of engineering — and I use the term in its broadest sense.

The material progress of the world is being advanced in three broad fields of activities, — production, transportation, and what some call our "communal relations"; that is, the activities consequent upon the gathering together of people in communities, towns and cities. In each of these three fields the engineer is a most important factor, and in each the progress achieved depends more than anything else upon the advancement made by the engineering profession.

Take production of commodities and we find that practically every activity in this field depends upon the work of the engineer. To begin with, in order to produce something, mankind must have materials to work upon. These must be obtained from the soil, as by agriculture or forestry, or from the depths of mother earth, as by mining. In all of this work the engineer is much in evidence, for even the success of modern agriculture is to-day largely dependent upon machinery and the implements which engineers produce, as well as upon irrigation. To change raw materials into finished products it is necessary to develop and utilize power in various ways, and here the engineer is especially useful, from the mining of coal and the building of dams to the construction and operation of power plants. The

power thus obtained is utilized in a multitude of machines which transform raw materials into manufactured products necessary or useful for the comfort and well-being of mankind, and the development of machinery in all of its forms is the work of the engineer.

As production passed the point of supplying merely the needs of bare savage existence, there was developed the important field of transportation — the movement of people and commodities from one place to another by land and by sea, and (in the present century) by air. In order that there may be transportation, routes have to be provided, necessitating the building of highways, railroads, canals, bridges and the like; vehicles of various kinds are required, as wagons, automobiles, the rolling stock of railroads, and ships, and for most of these special means of mechanical propulsion are necessary. With the growth of transportation, great land and water terminals are built and equipped with various devices for the expeditious and economical handling of passengers and freight in large quantities. Under the heading of transportation we may include, too, the transmission of intelligence by telegraph and telephone. The whole broad field of transportation has been made possible only by the work of the engineer, and to him the world looks for all future progress.

The development in the fields of production and transportation have made necessary the gathering together of people in towns and cities, and existence in such communities would not be possible were it not for the engineer. The larger the community, the more necessary and the more important and complicated does the engineer's work become. Cities cannot exist without systems of water supply and sewage disposal, the construction and maintenance of streets and pavements, the disposal of wastes, and the introduction of central systems for supplying light, heat and power; and in communities of any considerable size the development of means of internal communication by street railways, elevated railways and subways, all of which latter really belong to the broad field of transportation.

The world's advance in these three great fields of activity has been slow and gradual until within a comparatively brief

period, when progress in these lines has made wonderful strides. There are members of the Society who have been eye-witnesses of the tremendous advance in the past sixty or seventy years. Will the world's progress which made such a wonderful start during the nineteenth century be checked during the twentieth? Will the rate of advance during the lifetime of our children be any less wonderful and rapid than it has been in the lifetime of our fathers?

Of all the professions, the profession of engineering, in its broad sense, contributes most to the welfare and advancement of mankind. Even far more important than the medical profession is the profession of the engineer, for while medical men seek to cure disease, the sanitary engineer is constantly at work to prevent it. In every field of activity the world is coming more and more to depend and rely upon engineers; and, as the field has grown and broadened during the nineteenth century, so I believe will it continue to grow and broaden during the twentieth. But to meet these demands engineers themselves must grow and become broader men. The successful engineer of to-day and of to-morrow cannot be like the engineer of yesterday, who too often would "retire into the technical recesses of his professional work and content himself with being the servant of other men." On the contrary, if he would stand high in his profession, the engineer of to-day should be a broad-gage man, aggressive, alert, in touch with public questions outside his own narrow field, and a leader — not a follower — of men. It is upon the development of these qualities in engineers themselves that the whole future success of the profession depends, as well as to a considerable degree the advancement and the material progress of the world during the twentieth century. As a president of the American Society of Mechanical Engineers recently said, "Engineering is the profession of the present and will dominate the future." This will be true provided engineers themselves wake up to their opportunities and fit themselves to assume the greater responsibilities which the world is ready to place upon them.

The Training of the Engineer.

What are the qualities which fit a man for success in the profession of engineering? The ideal engineer must be a scientific man and at the same time a business man. To quote from an article by one of the past presidents of this Society[1]: "He must have a thorough knowledge of the laws of nature, the fundamental principles of mathematics and mechanics, and the materials of construction, for his work consists in applying those laws, principles and materials so as to make them of use in the world's business. He must be essentially a man of action. The engineer takes the discoveries of the scientist in his laboratory, or the bookworm in his study, and makes them available for the use and convenience of man. His dominant quality must be practical common sense, combined with habits of care and accuracy, and with the courage and training which will enable him to solve new problems and to meet emergencies with success." To these qualities I would add the quality of imagination. A recent president of the American Society of Civil Engineers[2] has said: "We do not consider imagination, ordinarily, as an important quality in the engineer, yet I think no engineer ever rises to eminence in his profession without it. Ex-President Eliot of Harvard, one of the most eminent educators in the world, says it is just as important to the engineer as to the artist and literary man, and that the engineer should stand with his feet on the ground and his head in the skies."

The foundation of an engineering career should preferably include a good technical school training, although this is not absolutely necessary, and we find that many of the most successful engineers of to-day are men who began their careers as apprentices in an engineer's office, gaining experience and studying at the same time. Much can be accomplished in this way by the novice in engineering, provided he finds employment with the right kind of an engineer, and provided also that he has the pluck and strength of character to apply himself assiduously to study in connection with his engineering work. Too often these men

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[1] Geo. F. Swain: "Engineering. Civil," Encyclopedia Americana.

[2] Mordecai T. Endicott; Trans. Am. Soc. C. E., Vol. LXXIII, p. 395.

fail because of lack of "stick-to-it-iveness." Independent study of this kind is necessarily slow and usually unbalanced and incomplete, and the young man seeking to enter the engineering profession will find a great economy of time as well as much greater breadth of training if he take a course in a technical school. No amount of schooling alone will ever make an engineer, however, and unless he have other qualities than the mere faculty of assimilating knowledge, the young man will fail as an engineer in spite of the best technical training; while, on the other hand, the man without the training of a technical school, but who possesses these qualities, will achieve success in the profession.

The best technical school training is one which gives a thorough grounding in the fundamental subjects of science and engineering without frills and specialties. Too often the young student seeks to get in a four years' engineering course a highly specialized training in some particular engineering branch. In response to popular demand there has been in most of our technical schools, during the past few years, a tendency to too high a degree of specialization. Fortunately a reaction is setting in, and in the best technical schools to-day courses are being rearranged so as to give the student a more thorough training in science and the general principles of engineering, with less specialization. It is a very common thing for the young engineer on leaving a technical school to enter a different line of work from that which he had in mind when he began his work as a student. This is so common that it may almost be said to be the general rule. With a thorough grounding in general principles in a technical school course there is no reason why the young engineer, by his own efforts in after study, should not fit himself for successful work in any branch of the broad profession of engineering.

Thorough preparation in the fundamentals of science and engineering is, however, but a part of the training necessary for the young man who is to become a successful engineer. In addition, much time should be given to the study of those subjects of a general nature which are necessary for every thoroughly educated man. "The engineer of the past has too generally

been considered a mere builder, and he has not as a rule been given the position to which his responsibilities and his achievements legitimately entitle him; but the engineer of the future should aim to take a position in society and business as a cultivated and highly trained man, on a level with men in any of the other professions."[1] The young engineer should have a general knowledge of business, "for engineering is business and business is engineering," and this may be obtained in part in the technical schools by a study of economics, business law and business methods. Some knowledge of the laws of business, and especially of the laws of contracts, is absolutely essential to every engineer who finds himself in charge of important engineering work.

There is one quality of highest importance to the success of the young engineer, which cannot be taught in schools and which he must gain for himself, and that is the ability to properly meet and mingle with his fellow-men. In other words, he should be what is popularly known as a "mixer," and failure in this direction is responsible for the lack of, or limited, success of many an engineer who has the other requisites, and who but for this lack would undoubtedly achieve a far higher position. "To be an engineer of material only is to be but a subordinate element in a profession which has contributed, and will continue to contribute, more to the advancement of civilization than all others combined. Rather should he strive to become an engineer of men."[2]

In a recent presidential address delivered before the American Society of Civil Engineers[3] it is stated of the engineer: "His training and practice have taught him to regard himself as separated from his fellow-men, with the result that he becomes the tool of those whose aim is to control men and to profit by their knowledge. The end is that he is a servant where he should be a master. Herein lies the weak point in the profession — may I be pardoned for naming it professional narrowness, while I try to point the way to convert weakness into strength. It is

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[1] Geo. F. Swain: "Engineering. Civil," Encyclopedia Americana.

[2] Charles Macdonald; Trans. Am. Soc. C. E., Vol. LXI, p. 546.

[3] Onward Bates; Trans. Am. Soc. C. E., Vol. LXIV, p. 573.

necessary for the engineer to be more of a 'mixer' than he has been, and to assume the initiative in many cases in which under similar conditions he has been a follower. He should be a manager, and should give orders to others who can do the work under his direction as well as he himself could do it with the situation reversed. It should not be considered unprofessional for an engineer to be a capitalist, and, when he takes his proper place as promoter and organizer and shares in the profits of engineering enterprises, he will no longer be taunted with the saying that 'an engineer is only good to spend other people's money.' It is by acquiring individual strength that the engineer can give strength to the profession. It is well known that engineers of admitted proficiency often have to work under the direction of men who are unfitted by education and experience to direct engineering work. This is because the engineer is a workman while the other party belongs to the class of 'managers.' The engineer has not reached his proper rank until he can hold the position of manager, as well as that of a designer and superviser of work. This is no plea for titles, since no title is more honorable than that of engineer, but it is a plain statement of present conditions. A better position will be secured whenever the engineer makes it his business to study men as well as materials, and to use men as he does machinery. The advancement must be individual, by fitting oneself for commanding duties, assuming those duties, and 'making good' in their performance."

In other words, engineers should not study nature alone but they should also study human nature. The higher an engineer rises in his profession, the more must he rely upon the work of others and the more will he come in contact with men in other professions and other walks of life. The engineer's success will then be measured by his ability to select competent assistants and advisers as well as by his ability to meet other men, to understand their points of view, and to present his views in terms which they can clearly understand. No engineer can successfully meet these requirements unless he begins young to mix with his fellows, not only with those in his own narrow special line of engineering work, but with others throughout the broad field of

his profession and especially with men in various other walks of life.

The Public and the Engineer.

The feeling is general among us that the public does not sufficiently appreciate the value of the work of engineers, and does not give the engineering profession the recognition to which it is due. As an engineering friend of mine[1] recently expressed it: "In the bucolic mind, the land surveyor and the engineer are one, and the locomotive runner or the man who runs the mill is looked upon as rather a higher type of engineer. To most people the name — engineer — applies to all men who operate steam or electric machinery or who survey land equally with those who locate and construct railroads, design bridges, water-works, sewers, etc., and direct the multitudinous activities connected with the complex civilization of the twentieth century. They confuse the engineer proper with the mechanic, artisan and skilled laborer, holding us, perhaps, a littler higher than the rest. The public associate the engineer with construction as they see it going on before their eyes, in buildings, bridges, sewers, etc. They do not distinguish between the superintendent, who may be and often is an engineer, and the foreman of a gang. An instrument man giving elevations represents the typical engineer to them far more definitely than would a sight of the chief in his office working over his plans."

The otherwise intelligent public has little or no conception of the importance and magnitude of the office side of engineering work. For example, if city authorities lay out a street and make an appropriation for its construction, it is hard to understand why a contract for the work cannot be let the next morning, and actual construction begun immediately. Or, if a bridge is to be constructed, what is to hinder calling in the representatives of bridge companies and saying to them, "We want a bridge so long and so wide to carry such and such loads. What will you build it for?"

The idea that to secure economical results it is necessary

[1] Edward E. Wall: "The Status of the Engineer," Journal Assn. Eng. Soc., Jan., 1914

to carefully plan work of this sort in the office before calling for bids and beginning actual construction, is foreign to the average lay mind.

To the engineer the lack of appreciation by the public is frequently painfully apparent, particularly when measured in terms of dollars and cents; but are we not ourselves largely responsible for this situation? The general public can learn of the qualities of engineers and the work that they do only from stories written by the reporters of local newspapers, and in the public press to-day, except for some notable undertaking like the Panama Canal, the work and achievements of engineers receive far less newspaper space than is given to members of other professions and other callings. The chief reason for this, I believe, lies with engineers themselves. They are far too content to keep in the background. They are accustomed to doing things and not to writing or talking about them. They seldom take an active interest in the questions of the day, local, state and national, and rarely do they participate, as they should, in public affairs. The architects are ahead of the engineers in that through their professional societies they apply themselves to problems affecting the public welfare, particularly to city planning, and to many public questions concerning the development and improvement of our cities, especially along artistic lines; but how much greater is the opportunity for collective work along similar lines by engineering organizations!

"Practically everything of a communal nature that appertains to the comfort, convenience, luxury and necessity of the dweller in cities — all, in fact, that makes possible the existence of cities — is the work of the engineer."[1] Is it not the duty of the engineer, even more than of the architect, to study these questions in their broad sense, and to take an active part in promoting the welfare of the community as a whole? The engineer of ability, experience and success in his profession should be considered as large a factor in the life of his city as the lawyer, merchant, banker or physician.

In another way, I regret to say, are engineers frequently responsible for the low estimate which the public places upon

[1] Edward E Wall: "The Status of the Engineer," Journal Assn. Eng. Soc., Jan., 1914.

the value of engineering services. Chief engineers of corporations and public boards too often make the mistake of hiring engineering assistants at the lowest possible wage, under the false impression that by such rigid economy they are enhancing their own value in the minds of their employers. Many of us can name instances where young engineers of much ability and good training, but of somewhat limited experience, have been placed in charge of important pieces of work at salaries less than the lowest wage paid to skilled workmen employed by the contractors working under their direction. Such practices do grave injury to the whole profession and cheapen it in the estimation of the public. Furthermore, they tend to react to the disadvantage even of the chief engineer, for his employers will reason that if the rank and file of engineers can be hired so cheaply, engineers as a whole are a cheap lot, and high salaries are not necessary in any grade, even that of the chief engineer himself. "Cheapening men ultimately means inferior work, which is bound to result in breaking down the standard of the profession."[1] It may be argued that salaries are regulated by the laws of supply and demand, yet the chief engineer who pays a fair wage, taking account of the time and money which the young engineer has spent in securing his education and training (his working capital), will not only secure better, more loyal and more efficient service, but will help to raise the standard of the whole profession, his own included.

The Work of the Boston Society of Civil Engineers.

In the presidential address delivered before our Society two years ago, it was stated, "It is time that this Society, which is a strong one, should make itself felt to a much greater degree in public enterprises, in the forming of public opinion, and in the various phases of our government." In this and in other ways I believe that the Society can do much to advance the standing of the engineering profession and the welfare of its members. The Society, it is true, is but the aggregation of its individual members, but if, individually, we come to realize the necessities of the situation, and the opportunities for improvement that lie

[1] Edward E. Wall: "The Status of the Engineer," Journal Assn. Eng. Soc., Jan., 1914.

before us, we may, by concerted action, succeed in raising to some degree the standard of the engineering profession in the minds of the public in this community.

Perhaps the first step to be considered is that of publicity, and in this connection the Cleveland Engineering Society has set all of us a good example and pointed the way to effective work. Most of you probably read a few weeks ago in one of the engineering papers an article on "Publicity Work of the Cleveland Engineering Society,"[1] as well as the editorial comment on that article. About a year ago that society awoke to the fact that engineers and engineering work in and about Cleveland were not receiving the attention which they should in the local press, and by the appointment of a committee on publicity steps were taken to remedy the difficulty. The editor of one of the daily papers expressed the opinion that one reason why news of an engineering nature does not get into the daily press is because the ordinary reporter does not have the technical knowledge to properly handle it, and he suggested that the society should be its own reporter. It is not often that engineers are found who have the faculty of writing a newspaper story and describing engineering work in a manner which will hold the interest of the non-technical reader. If, however, engineers had a sufficient breadth of view, the faculty of clearly expressing their ideas on paper, and, above all, the ability to see their own work from the point of view of other people, a task such as this publicity work should not be difficult. The Cleveland Engineering Society was fortunate in having for the chairman of its publicity committee just such a man, and the results obtained during the past year have been most gratifying, and they undoubtedly serve to raise in a substantial degree the estimation in which engineers are held by the Cleveland public. The editorial comment on the article to which I referred states: "There will be those, doubtless, who will say that such publicity work is undignified and even unprofessional. Such a viewpoint betrays dense ignorance of actual conditions at the present day. It is of the greatest importance, both for the welfare of the public and the engineering profession, that the public should have a more intelligent understanding and appreciation

[1] *Engineering News*, Jan. 22, 1914.

of the work of the engineer. Every engineer of long experience can recall many cases where the greatest difficulty he has had to contend with has been to make those for whom he was working — public authorities, boards of directors or private clients — understand and appreciate the importance of the particular task in engineering under consideration, and the need for its study on broad lines. . . .

"Every large business organization nowadays recognizes the great value and importance of publicity, and this not merely from the point of view of the sales department alone. High standing and reputation in the community are just as important a factor to a corporation or a firm as they are to an individual. Exactly the same rule applies to a profession. Any method by which it may have its work, its achievements, its standards and its aims laid before the public which it seeks to serve is a matter deserving serious attention."

There are many ways in which this Society may actively participate in public affairs to the mutual benefit of the community and our profession; and in this connection we may well take note of the work of that efficient business organization, the Boston Chamber of Commerce. That body, through its committees, is constantly studying live questions of local interest, many of which are more or less of an engineering character. Among them may be mentioned the agitation for the provision of a 40 ft. channel as well as numerous other improvements for Boston Harbor, waterway developments throughout New England, the White Mountain forest reserve, fire prevention, the modification of our city building laws, street improvements and comprehensive city planning. These are but a few of the many lines of investigation which the Boston Chamber of Commerce has recently undertaken, and they are typical of the public questions which should be considered. In much work of this character the Boston Society of Civil Engineers might well coöperate with the Boston Chamber of Commerce, and if this Society will but shake off its lethargy, and undertake to apply itself to the solution of some of the live questions of the day, it will find plenty of work cut out for it, and it will find, also, that it can be of real help to the community.

I am glad to say that the Society has only just rendered a public service whose importance we may not appreciate. In securing the paper on Boston foundations, with its compilation of a vast amount of information regarding soil conditions in all parts of the city, together with the extended discussion which this paper brought forth, the Society has rendered a real service to the community, and especially to architects and builders and others besides engineers who have to do with the building operations in this city. To render this particular service complete, this paper, with its diagrams and the full discussion, should be reprinted and made available to all who wish to use it.

I am well aware that many of the views which I have expressed will not be accepted by all who are present, and of those who differ from me many will be found who complain of the present status of the engineer. To my mind, we must face conditions squarely, and work individually and concertedly to improve them or else hold our peace. It is for us to chose between pessimism and progress.

Conclusion.

To sum up briefly, the message which I wish to convey is this: that, as I see it, the engineering field is broadening, opportunities are multiplying on every hand, and the outlook for the future is bright; but the times demand that the engineer be of a higher and much broader type than he has been heretofore. We must be much more than simply engineers in the old and narrow sense; we must be men of affairs, aggressive and alert, with the courage of our convictions and in touch with public questions. Individually and collectively, we must take our share of the world's work and actively participate in the solution of the pressing public questions of the day. If we engineers, as individuals, awake to the opportunities and the responsibilities that lie before us, and fit ourselves thoroughly for the higher duties that await us, we may be sure there will be no flagging in the world's material progress during the twentieth century, and that, in due time, the engineering profession will receive that degree of recognition to which it is justly entitled.

Vol. I MAY, 1914 No. 5

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

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REPORT OF COMMITTEE ON SEWERAGE STATISTICS.

BOSTON, MASS., March 4, 1914.

SANITARY SECTION, BOSTON SOCIETY OF CIVIL ENGINEERS,
BOSTON, MASS.:

Gentlemen, — Your Committee on Sewerage Statistics appointed in accordance with the vote of the Section on December 3, 1913, " . . . to report . . . on the advisability of continuing the collection and tabulation of sewerage statistics by the Section, and the form of blank to be recommended . . . "; begs leave to report as follows:

It may assist in a clearer understanding of the present status of this question, briefly to review the work of previous committees and the conclusions reached by them.

At the first annual meeting of the Sanitary Section, held March 2, 1904, it was voted "that a committee of five be appointed by the chair to consider the subject of 'Uniform Statistics of Sewer Maintenance,'" and the following were appointed to serve on that committee: Bertram Brewer, W. D. Hunter, Irving T. Farnum, W. D. Hubbard, H. P. Eddy.

The report of that committee was presented on March 7, 1906, and the form recommended for the presentation of sewerage statistics, with which you are familiar was adopted by the Section on June 9, 1906.

NOTE. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, by August 15, 1914, for publication in a subsequent number of the JOURNAL.

At the annual meeting of the Section on March 4, 1908, a "Committee on Collection and Tabulation of Sewerage Statistics" was appointed, consisting of Harrison P. Eddy, Charles Saville and Bertram Brewer. That committee presented a report, dated May 8, 1908, including tabulations of statistics relating to sewerage and sewage disposal, secured from twenty-four municipalities for the year 1906. That report was subsequently printed in the *Journal of the Association of Engineering Societies*, Vol. XL, No. 5, for May, 1908.

On February 3, 1909, the same committee presented a report embodying tabulations of sewerage statistics collected from forty-eight municipalities for the year 1907. That report was published in the *Journal of the Association of Engineering Societies*, Vol. XLII, No. 3, for March, 1909. Those tabulations included more or less complete reports from twenty-five cities and towns in Massachusetts, four in New York state, two each in New Hampshire, Rhode Island, Pennsylvania and Utah, and one each in Connecticut, New Jersey, Ohio, Indiana, Illinois, Michigan, Colorado, Kentucky, Minnesota, Washington and the Dominion of Canada, — a total of forty-eight municipalities, thirty-three having a population of over thirty thousand.

The collection and tabulation of those statistics involved a large amount of work, and the Society is greatly indebted to the members of that committee for bringing together a vast amount of useful information. The final report of the same committee was made on March 6, 1912. In that report, the committee stated as follows:

"The form of statistics adopted by the Section has been adopted by several city officials and embodied in their annual reports. The committee feels that this forms a valuable part of the reports, and that its use should be encouraged. To this end your committee recommends that the printed blanks in its possession be turned over to the secretary of the Section, and that he be requested to make reasonable effort to have city officials interested in this line of work adopt this form and embody it in their annual reports.

"The committee is of the opinion that it is unnecessary for the present to continue the collecting and compiling of sewer-

age statistics, as was done for one or two years, and suggests that the committee be now discontinued."

Apparently, one of the objects sought by the original committee was to induce the Bureau of the Census to accept the form recommended by the Section for the publication of sewerage statistics, which the Census Bureau had already undertaken in a small way. In the annual report of the Executive Committee of the Sanitary Section, March 6, 1907, is given a copy of a letter written to Mr. M. N. Baker by LeGrand Powers, chief statistician of the Bureau of the Census, Washington, D. C., February 23, 1907, in which Mr. Powers makes the following statement:

". . . it seems to me that the true position of the census with reference to the schedule of the Boston Society of Civil Engineers is as follows: The Census Office accepts that schedule tentatively as a basis of future work, and will proceed to make use of the same in the collection of data for its statistical publications so soon as a sufficient number of cities, through their engineering department, adopt that schedule in recording data. . . ."

Last year the Department of Commerce, Bureau of the Census, William J. Harris, director, published a volume entitled, "Special Reports, General Statistics of Cities, 1909, including Statistics of Sewers and Sewage Disposal, Refuse Collection and Disposal, Street Cleaning, Dust Prevention, Highways, and the General Highway Service of Cities having a Population of over 30 000. Prepared under the Supervision of LeGrand Powers, Chief Statistician for Finance and Municipal Statistics," in connection with which eleven "general tables" are presented, embodying sewerage statistics collected from one hundred and fifty-eight cities of over 30 000 population for the year 1909. The data given in these tables are shown by the following headings for each table, taken from the report:

TABLE I.

SEWERS — GENERAL STATISTICS OF SEWER SYSTEMS. 1909.

City Number.	City.	Population.		Area (Acres) Served by Sewer System. (Estimate.)	Mileage of Sewers.								
						Classified by Character.			Classified by Construction Material.				
		Total.	Served by Sewer System. (Estimate.)		Total.	Sanitary.	Combined.	Storm Water.	Stone.	Brick.	Brick and Concrete.	Brick and Stone.	Concrete.

Mileage of Sewers. (Cont'd.)				Number of Manholes.		Number of Catch Basins.		Number of Inverted Siphons.	Number of Storm-water Overflows.	Number of Outlets.	Cost of Replacement Value of System.	Expenses of Operation and Maintenance.			City Number.
Classified by Construction Material. (Cont'd.)															
Reinforced Concrete.	Vitrified Pipe.	Cement Pipe.	All Other.	Total.	Per Mile of Sewer.	Total.	Per Mile of Sewer.					Total.	Per 1 000 Population Served.	Per Mile of Sewer.	

TABLE 2.

SEWERS — MILEAGE AT CLOSE OF YEAR, CLASSIFIED BY CHARACTER AND BY MATERIAL OF WHICH CONSTRUCTED. 1909.

City Number.	City.	Total.	Mileage of Sewers.													
			Sanitary.				Combined.					Storm Water.				
			Total.	Brick.	Vitrified Pipe.	All Other.	Total.	Brick.	Concrete.	Vitrified Pipe.	All Other.	Total.	Brick.	Concrete.	Vitrified Pipe.	All Other.

TABLE 3.

SEWERS — MILEAGE BUILT DURING YEAR. 1909.

City Number.	City.	Total.	Classified by Character.			Classified by Builder.											
						City Employees.						Contractors.					
			Sanitary.	Combined.	Storm Water.	Total.	Brick.	Concrete.	Reinforced Concrete.	Vitrified Pipe.	All Other.	Total.	Brick.	Concrete.	Reinforced Concrete.	Vitrified Pipe.	All Other.

TABLE 4.

SEWERS — EMPLOYEES AND EXPENSES OF OPERATION AND MAINTENANCE. 1909.

Part I. Cities having No City Employees Engaged on Sewer Construction Work.
Part II. Cities having City Employees Engaged on Sewer Construction Work.

City Number.	City.	Total Mileage of Sewers.	Average Number of Employees.									Expenses of Operation and Maintenance.		
			All Classes.			Superintendents and Engineers.	Foremen and Inspectors.	Mechanics and Skilled Laborers.	Teamsters.	Unskilled Laborers.	All Others.	Total.	Per Mile of Sewer.	Per 1 000 Population Served.
			Total.	Per Mile of Sewer.	Per 10 000 Population Served.									

TABLE 5.

SEWERS — HOUSE CONNECTIONS. 1909.

City Number.	City.	Total Mileage of Sewers.	House Connections.							
			At Close of Year.			Made during Year.			Size (Inches).	Number of Stoppages.
			Number.	Length. (Miles).	Average Length. (Feet).	Number.	Length. (Feet).	Average Cost per Foot.		

TABLE 6.

Sewers — Flushing of Sewers and Cleaning of Sewers and Catch Basins. 1909.

City Number.	City.	Total Mileage of Sewers.	Kind of Sewer.	Flushing of Sewers.					
				Miles Flushed during Year.	Schedule of Flushing.	Flushed by Hose Attached to Hydrants.	Flushed by Specified Number of		
							Direct Connections with Water Mains.	Automatic Flush Tanks.	Portable Flush Tanks.

Cleaning of Sewers and Catch Basins.								City Number.
Sewers.				Catch Basins.				
Number of Stoppages in System during Year.	Number of Miles Cleaned during Year.	Cost of Cleaning per Mile.	Method of Cleaning.	Total Number.	Number Cleaned during Year.	Cubic Yards of Silt Removed per Basin per Cleaning.	Number of Specially Constructed Wagons for Removal of Silt.	

TABLE 7.

Sewers — Discharge of Sewage. 1909.

City Number.	City.	Volume of Sewage Discharged.					Stream or Body of Water into which Sewage is Discharged.
		Estimate of Discharge Based on	Daily during Year. (Gallons.)				
			Average.	Maximum.	Minimum.	Average per Person Served.	

TABLE 8.

Sewers — Pumping of Sewage. 1909.

City Number.	City.	Sewage Pumped during Year.				Daily Capacity of Pumps. (Gallons.)	Average Static Head against which Pumps Work. (Feet.)	Kind of Power Used in Pumping.	Average Number of Employees at Pumping Station.	Expenses of Pumping Station for Year.	
		Total Quantity (Millions of Gallons.)	Per Cent. of Total Discharge.	Million Gallons (average) per						Total.	Per Million Gallons Raised 1 Ft.
				Day.	Employee at Pumping Station.						

TABLE 9.

Sewers — Sewage Purification Systems. 1909.

City Number.	City.	Average Daily Quantity (Gallons) of Sewage Treated.		Sewer Systems for which Sewage was Purified.	Sewage Pumped.	Apparatus for Preliminary Process.	Tanks.		Filters.		Body of Water into which Effluent is Discharged.
		Total.	Per Cent. of Total for City.				Kind.	Number.	Kind.	Number.	

TABLE 10.

Sewers — Sewage Purification in Tanks. 1909.

City Number.	City.	Tanks.			Average Quantity (Gallons) of Sewage Treated Daily.	Average Detention Period. (Hours.)	Sludge.		Cost of				
									Construction.		Operation.		
		Kind.	Number.	Capacity. (Gallons.)			Amount (Cubic Yards) per Million Gallons of Sewage Treated.	Frequency of Removal.	Total.	Per Million Gallons Capacity.	Total.	Per Million Gallons Treated.	Per 1 000 Contributing Population.

TABLE 11.

Sewers — Sewage Purification in Filters. 1909.

City Number.	City.	Kind of Filters.	Date of Construction.	Number of Filters.	Area of Filters. (Acres.)	Depth of Filtering Material. (Inches.)	Dosing.		Quantity (Gallons) Treated Daily.			Per Cent. of Suspended Solids Removed.	Expenses of Operation.		
							Hours per Dose.	Times per Month.	Average.		Maximum.		Total.	Per Million Gallons Treated.	Per Acre of Beds.
									Total.	Per Acre of Beds.					

Remarks.

Tables 1, 2, 3, 4 (Parts I and II), 5, 6, 7 and 8 are arranged as follows:

Group I. Cities having a population of 300 000 or over in 1909.

Group II. Cities having a population of 100 000 to 300 000 in 1909.

Group III. Cities having a population of 50 000 to 100 000 in 1909.

Group IV. Cities having a population of 30 000 to 50 000 in 1909.

Tables 9, 10 and 11 are not grouped.

A comparison of these headings with those on the form recommended by the Section shows that the ground has been pretty well covered by the census. Some of the subjects on the form prescribed by the Section, not included in the census tables, are dealt with in the text, as, for example,

Methods of Financing the Construction Cost of Sewers.
Ventilation of Sewers.
Quantity of Factory Wastes.
Kinds and Quantities of Chemicals used in the Treatment.
Disposition of Sludge.

Concerning certain other subjects, information from a sufficient number of cities to tabulate could not be obtained apparently, such as,

The Number of Buildings Connected with the Sewers.
The Cost of Sewer Flushing.
Cost of Removal of Catch-Basin Material.
The Cost of Different Parts of the Treatment Works.
The Water Capacity of Contact and Trickling Filters.

The principal items on the Boston Society of Civil Engineers standard form not covered by the Census Report are as follows:

Total area city or town.
Cost of flushing per mile.
Cost of removing catch-basin material.
Number of buildings connected.
Leakage into sewers.
Description of pumping plants.
Description of fuels used, etc.
Average dynamic head.
Description of screens in connection with pumps.
Cost of filters.
Were loam and subsoil removed?
Character of filtering material.
System of underdrains.
Dosing apparatus and size of dose.
Method of caring for surface of filters.
Cubic yards material removed from surface.
Cost of removing same.
Are crops raised, etc.?
Amount received for crops.
Water capacity of contact or trickling filters and decrease since plant was started.

In the main, it will be found that the subjects upon which the Census Bureau does not report are relatively unimportant. On the other hand, there are several interesting items not called for in the form of the Sanitary Section, which are included in the census statistics, the most important being the following:

Classification of mileage of different types of construction built during the year by city employees and by contractors.
Number of employees of different grades on operation and maintenance of sewer systems at pumping stations and at treatment works.
Number of specially constructed wagons for grit chamber removal.
The basis for the estimation of sewage flow.
Daily capacity of pumps.
Depth of filtering material.
Number of sewer outlets.
Night soil disposal.

The committee feels that great credit is due the Census Bureau for collecting these valuable sewerage data and presenting them in such usable form. The scope of their work is much greater than any committee of this Section could hope to cover. Further, the census report deals in a similar manner with such kindred sanitary subjects as refuse disposal, street cleaning, dust prevention and general highway service, as well as statistics of salaries and wages.

In view of these facts, your committee recommends that the efforts of the Section to collect and tabulate general sewerage statistics be abandoned and that the same energy be applied along lines of special inquiry, as they become of interest. For example, it might be appropriate at the present time to consider the construction, operation and efficiency of tanks of the Imhoff type or sprinkling filters.

The Census Bureau does not at present collect statistics from municipalities of less than 30 000 population. In this connection, it might be stated that the census limit of urban population, up to 1880, was 8 000. Later, this limit was reduced to 4 000 and for the last census (1910) it was 2 500. Reasoning from analogy, it is probable that before many years the statistical work of the Bureau will be extended so as to include municipalities of less than 30 000 population.

The importance of sewerage statistics appears to be appreciated by the Census Bureau, and the incompleteness and inaccurateness of their records are acknowledged and pointed out. It is fair to assume, therefore, that as the years go on the census statistics will widen in scope and increase in accuracy. We believe that the Boston Society of Civil Engineers should do all in its power to assist the Bureau of the Census to accomplish this result, and your committee would respectfully suggest that the services of this Section be tendered to the Census Bureau to that end.

In regard to the blank form to be recommended to municipalities for reporting their statistics, we can see no legitimate reason to advocate anything but the census forms, which apparently have been based on the form recommended by this Society hitherto.

Respectfully submitted,

(Signed) Almon L. Fales,
Edwin H. Rogers,
George C. Whipple,
Committee.

DISCUSSION.

George A. Carpenter. — Under an article entitled, "A Brief Review of Recent Advances in Sewerage and Sewage Disposal," printed in *Engineering and Contracting* of February 25, 1914, a committee of the Illinois Society of Engineers reports as follows:

"This committee would urge upon all members of the Illinois Society of Engineers the endeavor to gather careful cost data, even though brief, and in particular to gather data on the cost of operation and maintenance of sewers and sewage pumping stations, wherever it may be within their power to do so. For the collection of such data and its report, a most useful form has been devised by the Sanitary Section of the Boston Society of Civil Engineers, which the members of this society could well follow, not alone for their private information, but for the use of the society as a whole and the service of the sewerage and sewage disposal committee in making up its annual statement. The committee urges that every member of the society who is responsible for the sewers of a community should endeavor to have his community make up its annual report along the lines of the standard form, and should endeavor to have these data in hand early enough for the use of the committee of this society each year. If this can be done, much useful information will be obtained of service not alone to the members of this society, but to all engineers interested in like pursuits."

Vol. I MAY, 1914 No. 5

BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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THE COLLECTION AND TREATMENT OF SEWAGE IN THEIR RELATION TO THE CITY OF PHILADELPHIA.

BY GEORGE S. WEBSTER, CHIEF ENGINEER.

(Presented before the Sanitary Section, March 4, 1914.)

SEWERAGE SYSTEM.

THE sewers of the city of Philadelphia as originally built discharged the crude sewage directly into the rivers and nearby streams, this not being considered objectionable at that time; but as the population increased and many tributary sewers were constructed, the smaller streams became seriously polluted and the Delaware and Schuylkill rivers, from which the city's water supply is taken, became so contaminated that in order to protect the public health it was necessary to take measures to alleviate the conditions.

The first work undertaken, commenced about the year 1883, was the construction of an intercepting sewer along the east bank of the Schuylkill River, from tidewater below Fairmount Dam to approximately the northern boundary of the city, with a main branch extending north along the Wissahickon Creek, thus keeping out of the water supply taken from the Schuylkill River all the sewage, collected in an extensive system of separate sewers, from Manayunk, Roxborough, Falls of

NOTE. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before August 15, 1914, for publication in a subsequent number of the JOURNAL.

Schuylkill and the portions of Germantown and Chestnut Hill lying in the Wissahickon and Schuylkill watersheds within the city limits. Recently an intercepting sewer has been constructed along the east bank of Cobbs Creek, to collect the dry-weather flow and first flush of the rain discharged from the combined sewers into that stream, which had become so seriously polluted as to be objectionable to sight and smell; and within the past two years an intercepting sewer has been built along the Pennypack Creek, in the northeastern part of the city, to collect the sewage from the village of Holmesburg and from three large municipal institutions and convey it to treatment works, where it is purified sufficiently to protect the water supply taken from the Delaware River.

The city of Philadelphia has therefore what may be considered three systems of sewers: The combined system which covers by far the larger part of the city, the separate system which has been adopted in the areas adjacent to the portion of the Schuylkill River from which the water supply is taken, and the intercepting sewers along Cobbs Creek and Pennypack Creek.

The city is now engaged in the preparation of a comprehensive plan for the collection and treatment of its sewage, for submission to the state department of health, and the work which is now being constructed is in harmony with the plans which will be recommended. The investigations which have been carried on include a large number of studies of possible methods of collecting the sewage, the operation of a sewage experiment station, sanitary surveys of the water-courses and rivers, and the construction and operation of a plant to treat the sewage in one section of the city adjacent to the water supply. The magnitude of the problem will be appreciated when it is considered that the area of the city is 130 square miles, that it has a population of 1 650 000, and that the water consumption is approximately 200 gal. per capita daily; this, with the infiltrated ground-water from the older sewers, produces at the present time a large volume of sewage estimated at 400 000 000 gal. a day.

The problem of sewage disposal in Philadelphia is two-fold: first, to collect the sewage from the present system and

abolish the nuisance which now exists in the large creeks and lower Schuylkill owing to the insufficiency of diluting water, and to carry it to distant points for treatment; and second, the protection of the public health by the treatment of the sewage, which is now and in the future will be discharged into the Delaware River, this treatment to be carried to such a degree that the drinking water can be safely and economically purified before delivery to the consumer.

It is of great importance, in preparing designs both for the collecting system and the treatment works, that relief may be given from the present objectionable conditions in the shortest possible time, that the work may be carried on economically and advantageously from time to time as funds become available, that each step taken may give some relief, and that it will not be necessary for the completion of the entire project before benefits may be obtained.

It was found early in the investigations that the cost of installing the separate system in those parts of the city already sewered on the combined plan would be prohibitive, for in addition to the cost to the city of laying sewage pipes in every street, the plumbing fixtures in all buildings connected to the sewer system would have to be rearranged so that the sewage and the rainwater could be carried in separate conduits. This latter expense, which would amount to many millions of dollars, would have to be borne by the individual owners.

In the design of sewers for the purpose of carrying sewage only, the factors used are the contributing population, water consumption and the amount of infiltrated ground-water. It is quite common practice in many cities in designing sewage sewers to calculate that they shall run half full, when carrying a water consumption of 150 gal. per capita from the population tributary. To reach a conclusion as to the quantity of sewage to be treated by the city of Philadelphia in the future, and to obtain data for the design of the intercepting sewers, gagings were made of the dry-weather flow of a number of main sewers, some of which were located in solidly built-up areas and others in partly built-up districts, and from the factors thus obtained estimates were prepared, based upon the probable increase and

density of population, of the quantity of sewage that must be cared for in the future, the estimates and population curves being projected to the year 1950.

The amount of sewage flow determined by the gagings in all cases included the infiltrated ground-water, no practical way appearing by which it could be differentiated from the sewage proper. As a majority of the sewers in which gagings were taken are of considerable size and length, the variation between the maximum, minimum and average rates of flow is not as great as in smaller sewers. The mean of all the gagings showed that the maximum flow was 128 per cent. of the average, and the minimum 78 per cent. of the average.

In addition to the flow of sewage, it has been decided to admit into the intercepting sewers, through automatic regulators, the first flush of the rain, which is usually as polluting as sewage, and the amount to be admitted has been fixed at 10 per cent. of the maximum dry-weather flow of the sewers, but a much larger percentage can be intercepted when the sewage is not flowing at a maximum rate. This additional 10 per cent. makes a storm maximum flow of 141 per cent. of the average flow.

When it is considered that the per capita consumption of water in Philadelphia is 200 gal. a day and that in the towns of England only about 40 gal. is used, it will be seen that by the arrangement proposed the degree of dilution of the sewage, in time of storm, compares well with the English practice of treating six times the normal dry-weather flow.

In studying the methods of disposal it has been found that the sewage may be treated with much less offense if it reaches the works in a comparatively fresh state before putrefaction has set in, therefore great care is being taken in the design of the sewer system that the velocity of flow shall not be less than that required to carry the materials in suspension. This is accomplished by providing proper gradients and by the exercise of care to secure smooth surfaces, avoiding all roughness and projections on the interior of the sewer where organic matter might find lodgment and be retained until putrefaction sets in and stench begins. Upon examination of many of the sewers in Europe there was no odor noticeable because the interior

surfaces were smooth, either vitrified tile or smooth glazed brick being used, and all connections so made as to provide a natural flow without the creation of eddies where deposits might occur. It is, therefore, recognized that a solution of a part of the problem of sewage treatment is to construct sewers with smooth interiors and to keep them clean and inoffensive.

In designing the collecting system, it is proposed to construct intercepting sewers at two levels, and in this way to utilize the potential energy in every foot of head and carry to the treatment works by the high-level intercepters the greatest possible volume of sewage, and thus reduce to a minimum the quantity to be pumped.

The collecting systems in many European cities are constructed so as to convey the sewage to one or more suitable locations for treatment, and care is exercised in their designs to secure the greatest economies.

Sanitary Surveys.

There are in Philadelphia five large creeks and the Schuylkill River, all of which are tributary to the Delaware River, which forms the eastern boundary of the city. Poquessing Creek flows through a territory but little developed and is therefore not at the present time polluted. The sewage formerly discharged into Pennypack Creek and Wissahickon Creek has been intercepted and the water in these streams restored to a normal condition. A large part of the sewage on the Philadelphia side of Cobbs Creek has been intercepted and the condition of the water in this creek greatly improved. Frankford Creek, which empties into the Delaware River about five miles south of the Torresdale Water Filters, flows in part through a densely built up and industrial part of the city and receives crude sewage from about 140 000 people. It has several dams along its length and therefore low velocities. The water is not only grossly polluted by the discharge of sewage into it, but the deposits of sewage origin upon the bed of the creek add to the nuisance.

The Schuylkill River flows through the city in a generally

southerly direction, and about midway there is a dam which forms the end of tidal influence. The section of the river north of the dam has been protected within the city limits by intercepting sewers. Into the tidal portion of the river below the dam, however, there is now being discharged the sewage from about 455 000 people. At times of drought almost the entire upstream flow is used for water supply, leaving a very inadequate volume of diluting water for the sewage from this large population. The examinations made during the summer months showed the water in this part of the river to be depleted of dissolved oxygen. Furthermore, the tidal velocities in the lower part of the Schuylkill River are insufficient to maintain the sewage matter in suspension, so that in addition to the polluted condition of the water, the putrefying deposits upon the bed of the river increase the nuisance, particularly in warm weather; but as in the case of Frankford Creek, above described, the natural sedimentation processes and the gasification of the resulting sludge, together with the refreshing action of the tide, lighten the load of organic matter placed upon the waters of the Delaware River.

The Delaware is one of the large rivers of the United States, and forms the natural drainage for portions of the states of Pennsylvania, New York and New Jersey. The normal flow of upland water is at the rate of 4 050 sec.-ft., in addition to which there is a tidal range of $5\frac{1}{2}$ ft., and it is estimated that during the ebbing of the tide 2 421 000 000 cu. ft. of water flow past the city. As the sewage of the city at present and the effluent from the treatment works in the future must be disposed of in the waters of this river, its present condition has been examined with considerable care and it was found that with the exception of the docks, where sewers discharged, the Delaware River is successfully disposing of the crude sewage of the present population of Philadelphia in addition to that of the neighboring towns. Even in summer weather and in times of extreme drought, there has been no nuisance or offense created, although the amount of dissolved oxygen in the river has been small. The surveys indicated that the river water after passing beyond the points of discharge of the sewage of the

city gained rapidly in its oxygen content. The high velocities, due to tidal flow in the river, maintain the sewage matters in suspension, and the examination shows that the entire bed of the river (excepting the docks) is clean and free from deposits of sewage origin.

It must, however, be realized that, with the increase in the population and the consequent added load placed upon the river, its oxidizing power will soon be overtaxed and that the time to begin the building of the collecting and treatment works is at hand.

Treatment Works.

The sanitary surveys of the water-courses in Philadelphia show that sewage must be excluded from the creeks and the Schuylkill River, and that the treatment works must be located so as to discharge their effluents into the Delaware River in order to utilize to the fullest extent the great diluting and oxidizing capacity of that river.

It is proposed to locate the first treatment works in the northeast section of the city. The collecting system tributary thereto will eliminate the pollution of Frankford Creek and also prevent the discharge of crude sewage into the Delaware River within the tidal influence of the Torresdale Water Filters which provide three-fifths of the city's water supply. The degree of treatment required at this works must therefore be based upon a hygienic standard in order that the public health will not be jeopardized by overtaxing the economical and safe operation of the water filters.

The second treatment works will be located in the southwest part of the city, near the mouth of the Schuylkill River, the most distant point within the city limits from the source of water supply. The collecting system tributary to this works will eliminate the pollution of the lower Schuylkill River and will result in concentrating the sewage from over half the population of the city at one point for treatment. As the effluent of this works will be entirely below the influence of the city's water supply, the degree of treatment required need only be sufficient to prevent nuisance in the Delaware River.

It appears to be economical to construct temporarily a clarification works in the southeast district, to care for the sewage now discharged into the Delaware River below the center of the city.

Treatment.

In selecting methods for the disposal of the great volume of sewage produced in large cities, the adaptability of the various processes to a comprehensive plan must be considered so that the treatment works may be constructed by successive steps as needs arise for more refined treatment and as funds become available. It is desirable to obtain intensive methods, so as to secure a maximum of efficiency upon a minimum area of land, but in all cases exercising care to prevent nuisance from odors.

Various methods for the treatment of the sewage of the city of Philadelphia were studied, and those best adapted to the local conditions selected.

It has been frequently urged that the sewage of the city could be purified to advantage by applying it to farm land. Mr. John D. Watson, after years of experience, aptly states that this method of disposing of sewage "may be ideal in theory, but it is difficult, if not impossible, to obtain the ideal on a farm of large size." Berlin and Paris dispose of their sewage in this way, but, owing to the small volume of sewage which can be treated per acre, large areas of suitable land are required.

The Metropolitan Sewerage Commission of New York City has estimated that 175 square miles of land would be required to treat the sewage of that city if it were applied at the rate of 12 000 gal. per acre, and that the cost of this method of treatment would be $153 000 000, and therefore dismissed it as being impracticable. The city of Birmingham, England, has abandoned its sewage farms and substituted the more intensive biological method, and the same course will probably be followed in Paris.

To treat at the present time the sewage of Philadelphia on farm land would require an area of approximately 60 square miles. To secure this amount of land in Pennsylvania adjacent to the city would be prohibitive on account of the cost, and

would be opposed by citizens and property owners, hence this method of treatment need not be further considered.

London, the largest city in the world, with a population of 6 000 000 people, situated on the banks of a river with but little larger flow of upland water than the Schuylkill, disposes of its sewage by removing about 75 per cent. of the suspended matter by chemical precipitation and depends upon the oxidizing power of the river to accomplish its ultimate purification. That this is being successfully accomplished may be seen from the diagram which was prepared by Sir Maurice Fitzmaurice, late chief engineer of the London County Council, showing the percentage of saturation of the Thames River with dissolved oxygen, in connection with which he states, "With respect to the minimum amount of dissolved oxygen that should be present to prevent offense, it is rather difficult to answer this exactly, but I may say that the only complaint in recent years was for a short time in 1901."

While this method has been successfully used in London, it would not be applicable to Philadelphia, on account of the long haul to dispose of the sludge in the ocean, over one hundred miles distant. Another objection is the large quantity of sludge produced. From the best information available, it appears that the sludge, containing about 95 per cent. water, resulting from this method of treatment, amounts to 800 tons per day for a population of 500 000 people.

The city of Manchester, England, has probably the largest installation of contact beds. These are found to be expensive to operate and fail to produce an effluent up to the requirements of the Rivers Board. The concensus of opinion among experts in England seems to be that contact beds for a large installation are not as efficient as percolating filters.

From the results obtained at the Philadelphia Experiment Station and from the plant in operation at the Pennypack Creek, confirmed by the testimony of the city engineers who inspected a number of plants in Germany, it has been found that the two-story sedimentation tank, known as the Emscher tank, offers the best solution for the preliminary treatment of the sewage. The advantages are that the separation of the settling sewage

from the digesting sludge maintains the sewage in as fresh a condition as it enters the tank, that it is equal in efficiency to any other type of tank in removing the suspended matter with shorter retention periods and that the sludge withdrawn is without offensive odor, is smaller in volume than sludges resulting from other processes and more easily dried, and is so thoroughly decomposed that it resembles garden soil and may be used for filling in low lands without nuisance.

It is the purpose to recommend for the northeast and southwest treatment works the following processes in sequence: Coarse screens to restrain the large floating objects, grit chambers designed to intercept the inorganic matter only, two-story sedimentation tanks of the Emscher type, and percolating filters or such other improved methods of oxidation as may be developed by the time this refinement is needed. All of these processes are so related that they can be incorporated in the work successively; each one is the most intensive of its kind, therefore a minimum amount of land will be required for the works.

At the Southeast Works it is proposed temporarily to clarify the sewage either by fine screening or by the tankage method and then to discharge it without further treatment into the river. If a more refined treatment is required in the future the effluent from this plant may be carried to the Southwest Works, where ample area is being provided for additional processes.

The full utilization of the diluting and oxidizing power of the river water largely depends upon securing a thorough mixture of the effluent from the works and the water of the river. At each of the three proposed treatment works for Philadelphia it is planned to accomplish this by discharging the effluent through submerged outlets into the main channel of the river.

The distribution of sewage over the surface of percolating filters is one of great importance, as efficient distribution will allow the use of high rates. At Bolton and at Hampton, in England, a traveling distributor is used. This requires but little head, but it is doubtful if it could be successfully used in countries subject to severe winter weather. At Wilmersdorf,

Germany, and in a number of English plants, there are percolator filter installations in which distribution is effected by means of rotary arms. This method accomplishes good distribution but has not been looked upon with favor in America. At Birmingham, distribution is through fixed nozzles operating under a constant head, and this method was followed in the early American installations, but it results in uneven application of the sewage. Latterly this has been improved by the use of the tapered dosing tank with syphonic discharge.

At the Pennypack Creek Works in Philadelphia there is in service a method of distribution through fixed nozzles, operating under a fluctuating head, which yields results equal to that from a mechanical distributor.

The Pennypack Creek Sewage Treatment Works.

As a part of the work of disposing of the sewage of the city and of protecting the water supply, a treatment works has been constructed and is now in operation on the banks of the Pennypack Creek which empties into the Delaware River 2 000 ft. from the Torresdale water filters. Into this creek there was formerly discharged the sewage of the village of Holmesburg and the large municipal institutions located nearby. Intercepting sewers have been built along the creek, and they conduct the sewage to a pumping station, where it is coarse-screened and passed through a grit chamber and then forced to the treatment works, one third of a mile distant. The plant is designed ultimately to treat 2 000 000 gal. per day and at the present time it is receiving approximately 1 000 000 gal. daily.

The sewage first enters two Emscher tanks, which are of the radial flow type, 30 ft. in diameter and 32½ ft. deep, and having a normal retention period of 2½ hrs. The sludge is withdrawn from the bottom of these tanks through a pipe line, and is discharged by gravity upon a sludge-drying bed composed of layers of sand placed upon broken stone and under-drained by agricultural tile. Instead of the usual method of collecting the effluent of the Emscher tank into a dosing tank from which it would be discharged by a siphon upon the percolating filter, an equalizing tank has been constructed into which the effluent

flows. The bottom of this tank is connected by a 24-in. cast-iron pipe with the distributing system of the percolating filter, and in this line between the equalizing tank and the percolating filter is placed a butterfly valve. The opening and closing of the butterfly valve is controlled by a cam, which is operated through gearing by a water-wheel driven by a small flow of Emscher tank effluent.

The shape of this cam was designed experimentally so as to make the spray from the fixed nozzles alternately move back and forth from the nozzle to a line which produces about six inches overlap of the sprays, and by this means a distribution has been obtained practically equal to that from a mechanical distributor.

To meet the variation in flow, due to the daily fluctation and to storms, the equalizing tank is electrically connected to the operating machine so that when the flow decreases and the level of the sewage in the tank falls to a predetermined elevation, the machine shuts down and the percolating filter is thrown out of service. When the flow increases and the water rises in the tank, a different cam from that generally in service is automatically thrown in, which causes a longer period of display of the nozzles and cares for the increased flow.

The percolating filter is one acre in area and is divided into five bays, each having its own main distributor. Taylor square nozzles are used, spaced 10.8 ft. apart. The medium is 6 ft. of crushed trap rock, from 1 in. to 3 in. in size. Semi-circular vitrified clay underdrains are laid on a concrete floor, which slopes to the main effluent collectors.

As the function of this plant is the protection of the water of the Delaware River in the immediate vicinity of the intake of the Torresdale water filters, the state department of health required the disinfection of the effluent of the percolating filters, and a plant for this purpose was installed on the line connecting the percolating filters with the final settling basin, consisting of a mixing tank, which rests on the floor of the house and from which the bleach cream is forced by a centrifugal pump to either one of the two solution tanks. Before the bleach solution is added to the sewage it is diluted by a stream of water, and

the very dilute solution flows through a lead pipe, perforated with a large number of small holes, and which lies horizontally in the channel carrying the effluent from the percolating filters. In this way a complete admixture of the disinfectant with the sewage is accomplished, and with only about 25 lbs. of dry bleach per day, which represents one part per million available chlorine, an almost sterile effluent has been produced. The records show that over a period of nineteen weeks only upon one occasion were B. coli found in the final effluent. After the sewage has been disinfected it is retained for about two hours in a shallow final settling basin and is then discharged into the creek.

The sewage as received at the treatment works is both fresh and dilute, and by keeping clean the surfaces with which it comes in contact, and by passing it through each of the processes as rapidly as possible, the plant is operated without any odor.

The grounds around the works have been made attractive by the maintenance of well-trimmed grass areas and by planting shrubs and flowering plants.

The sludge withdrawn has been low in moisture, generally about 75 per cent., has contained a considerable amount of gas, and each time it was withdrawn it has been found to be blacker and more granular, showing that the ripening period has been passed and that typical sludge has been obtained.

The final effluent as discharged into the creek has invariably been free from an appreciable amount of suspended matter, perfectly stable and nearly sterilized.

The work so far accomplished has demonstrated the feasibility of the methods suggested for the comprehensive treatment of the sewage of the city. The state board of health having been in touch with the work so far completed, it is anticipated that the plans to be recommended will meet with its approval; and it is hoped that funds will soon be available to commence the work on the larger installations.

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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

RUN-OFF FROM SEWERED AREAS.

FINAL REPORT OF COMMITTEE.

MARCH 4, 1914.

TO THE SANITARY SECTION OF THE
BOSTON SOCIETY OF CIVIL ENGINEERS:

Your Committee on Run-Off from Sewered Areas herewith submits its final report.

This committee was appointed on May 1, 1907, following a meeting at which a general discussion of the measurement of storm-water flow in sewers was had. The original committee consisted of Irving T. Farnham, George A. Carpenter, Lewis M. Hastings, Harrison P. Eddy and Hector J. Hughes. Arthur T. Safford and William S. Johnson were added a little later. Mr. Farnham died September 19, 1908, and Harold K. Barrows was appointed to fill the vacancy in the committee, and at a later date its membership was further enlarged by the addition of George C. Whipple.

On January 1, 1908, your committee submitted a preliminary report designed particularly to describe the apparatus needed for the gaging of rainfall and run-off, and to offer such hints as might be of value to engineers contemplating the establishment of such apparatus. It also contained a partial bibliography of articles relating to maximum rainfall and storm-water

NOTE. Discussion of this report is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before October 15, 1914, for publication in a subsequent number of the JOURNAL.

run-off of sewers. Progress reports have been submitted to the annual meetings of the Section, on March 4, 1908; March 3, 1909; March 2, 1910; March 1, 1911; and March 6, 1912.

An examination of these progress reports shows that soon after its formation the committee was sanguine of securing the coöperation of a considerable number of engineers, who would submit from time to time the results of their gagings so that they might be brought together by the committee and made available for general use by the profession. As time went on, the reports of the committee show that even some of the engineers who had started gaging stations found the difficulty of maintaining them so great and the results obtained so unsatisfactory that they abandoned the work. Others found it difficult to interpret the results of their gagings, and turned them over to the committee in incomplete form. In the later reports, the committee indicated that it no longer hoped to receive the results of numerous gagings, but that some records of considerable value had been obtained which it was hoped could be interpreted and presented to the Society.

Your committee has now brought together all of the gagings which it has been able to secure, and has made such interpretation of the results as is practicable at this time, and presents the results herewith.

Any report upon this subject is naturally divided into three main parts, —

1. Methods of measuring precipitation.

2. Methods of measuring run-off.

3. Results of measurements of rainfall and run-off, showing relation between precipitation and flow in sewers.

Methods of Measuring Precipitation.

The automatic or recording rain gage is the only type which is of use in studies of this character, not only because it is essential that records be taken at the time storms occur, whether that be during the night or at other times when observers might not be on duty, but also and especially because it is the rate of rainfall, rather than total quantity, in which we are interested

in studies of this kind. This point is so fully recognized that it is not necessary to do more than refer to it at this time.

A point not always recognized in connection with automatic rain gages is the great importance of a good clock movement which can be closely and accurately regulated. In comparing the records of several rain gages, or the records of rain gages with those of sewer gages, the question of time is one of much importance. The correct time of starting a new gage sheet and of removing the sheet from the gage should always be distinctly marked upon the chart. With this information available, it may be possible to adjust the error so as to tell moderately closely the time of occurrence of a storm and the time occupied in travel of the storm.

With all commercial rain gages on the market, the only method of estimating the time is by noting the position of the pen upon the chart. It is seldom possible to estimate the time closer than five minutes, and frequently it is difficult to estimate it closer than fifteen minutes. It is, therefore, a difficult matter to regulate the clock, or to compare the time indicated by two or more gages. This would be greatly simplified if all gages of this type were furnished with clock dials and hands, in addition to the ordinary regulator, so that it might be possible to adjust the clock to the correct time and to keep the clocks of several gages properly synchronized. In large and important works the possibility of electrical operation of the clocks, thus insuring their keeping proper time and being absolutely synchronized, is worthy of consideration.

Automatic Rain Gages.

The principal types of automatic rain gages are the following: *

1. *The Fergusson Gage.* This instrument is made by the International Instrument Company, 23 Church Street, Cambridge, Mass., and costs about $80. The total height of the instrument is 32 ins. and the outside diameter 18 ins., the diameter of the collector ring being 8 ins. It has a total capacity of

* These descriptions have been quoted from the manuscript of a forthcoming "Handbook of American Sewerage Practice," by Leonard Metcalf and Harrison P. Eddy.

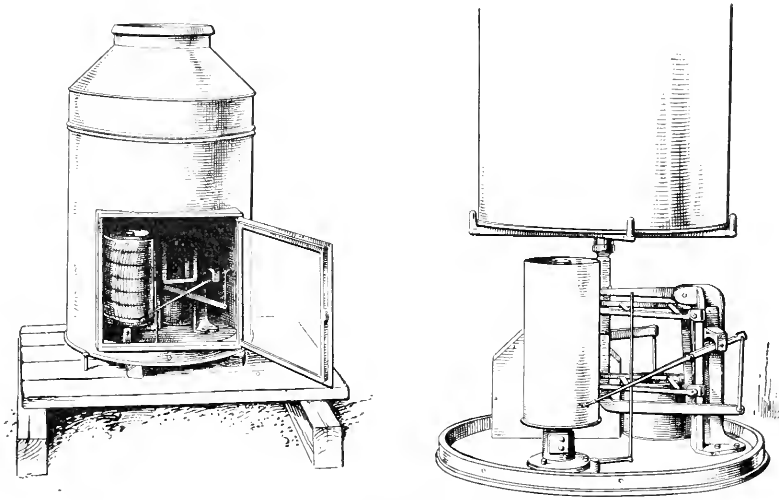


Fig. 1. Fergusson Rain Gage.

6 ins. of rain. The water received by the collector is discharged into a can supported upon a spring balance, the movement of which is transmitted by link motion to a pen moving through an arc of a circle and making a record upon a chart carried by a revolving drum. The length of the chart is 11 ins., repre-

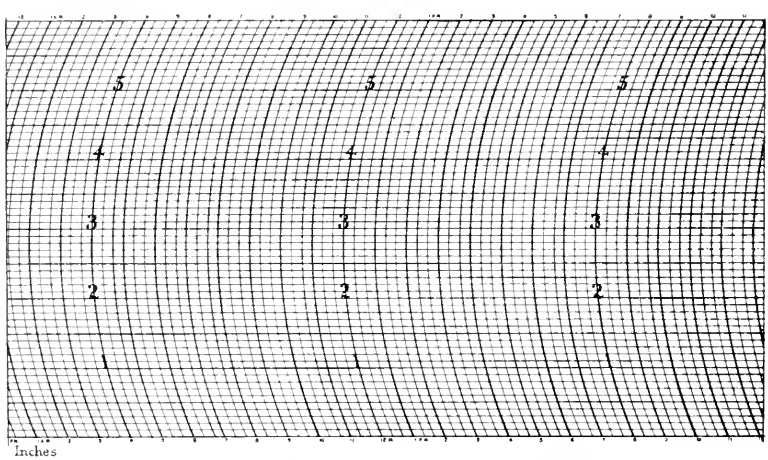


Fig. 2. Chart for Fergusson Rain Gage.

senting twenty-four hours of time, and accordingly the time scale is small. The height of the chart is 6 ins. and the precipitation is recorded to natural scale.

The advantages of this instrument are its comparatively small size and the fact that it is entirely self-contained and is not dependent upon the operation of electrical recording apparatus. The disadvantages are the very small time-scale, making it impossible to determine accurately high rates of precipitation, and the further fact that the pen moves in a curved line, rendering the chart somewhat difficult to interpret. Moreover, the link motion contains several joints and there is possibility of lost motion and friction in the joints.

FIG. 3. DRAPER'S SELF-RECORDING RAIN GAGE.

Illustrations of the gage complete, and of the working parts with the casing removed are shown in Fig. 1. The record sheet is shown in Fig. 2.

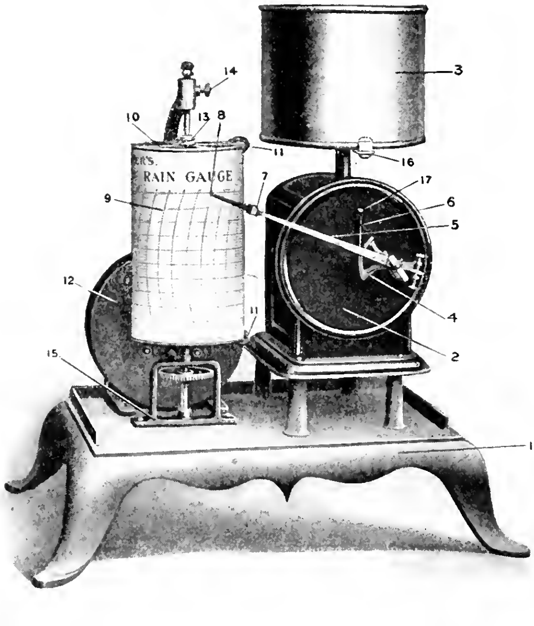


Fig. 3. Draper's Self-Recording Rain Gage.

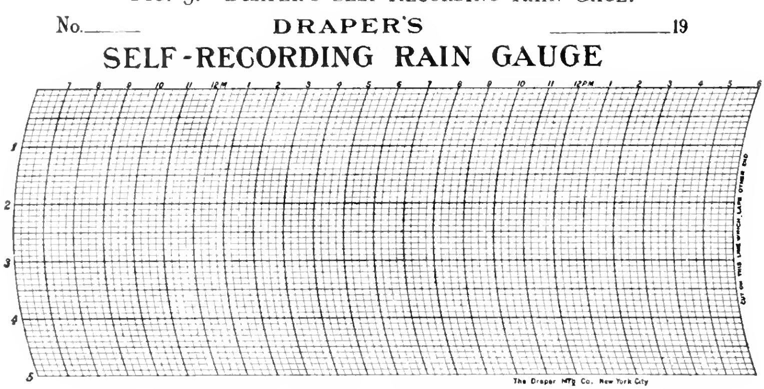


Fig. 4. Original is $12\frac{1}{2}$ ins. Long.

2. *Draper Gage.* The Draper Manufacturing Company, of 152 Front Street, New York City, makes the recording rain gage shown in Fig. 3. This gage is 26 x 15 x 10 ins. in size, weighs 45 lbs. and sells for $75. As will be seen from the illustrations, this gage is in general similar to the Fergusson gage. The principal differences are that the gage has a capacity of but 5 ins., instead of 6, the motion of the pen is from the top of the chart down instead of from the bottom up, and the time scale is slightly greater (if the clock is adjusted to revolve the

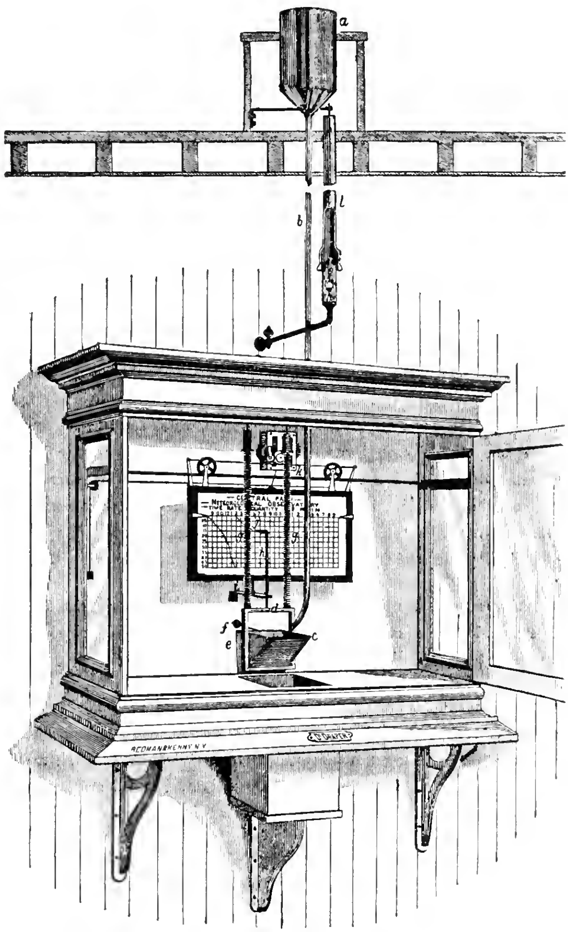


FIG. 5. DRAPER'S SELF-RECORDING RAIN GAGE. (OLD PATTERN.)

drum once each day). The circumference of the drum is about $12\frac{1}{2}$ ins., so that one hour of time corresponds to a little more than $\frac{1}{2}$ in. on the chart. Substantially the same comments apply to this gage as to the Fergusson gage, except those relating to the link motion. In the Draper gage, the arm carrying the pen is actuated by a fine wire passing over a quadrant instead of by a link motion.

2a. Draper Gage, Old Pattern. In the old pattern of the Draper gage, Fig. 5, the water is collected through a funnel placed on the roof of the building or chamber and conveyed through a tube into a tipping bucket suspended from two helicoi-

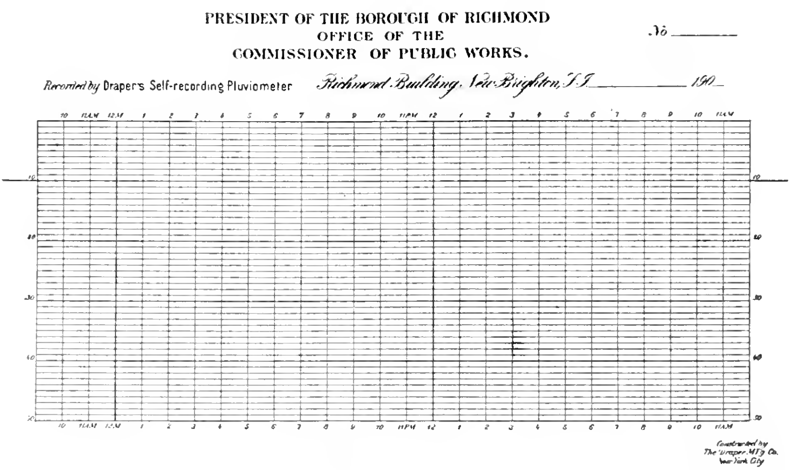


FIG. 6. CHART FOR DRAPER RAIN GAGE, OLD PATTERN. ORIGINAL IS 12 INS. LONG.

dal springs. These springs are so adjusted that the scale of precipitation is magnified ten times, — that is to say, 1 in. on the chart represents $\frac{1}{10}$ in. of rain. The pen arm is attached to the bucket and moves directly with it from the top of the chart to the bottom. When 0.5 of an inch of rain have been collected the bucket dumps and immediately returns to its upright position, bringing the pen to zero at the top of the chart.

The chart is carried on a flat plate suspended from a track, and moved by a clockwork. As originally constructed, the chart was made to represent one week of time, but more recently the clockwork has been modified so that the chart makes a complete traverse in twenty-four hours. It is, however, so short — the total length being 12 ins. — that the scale is very

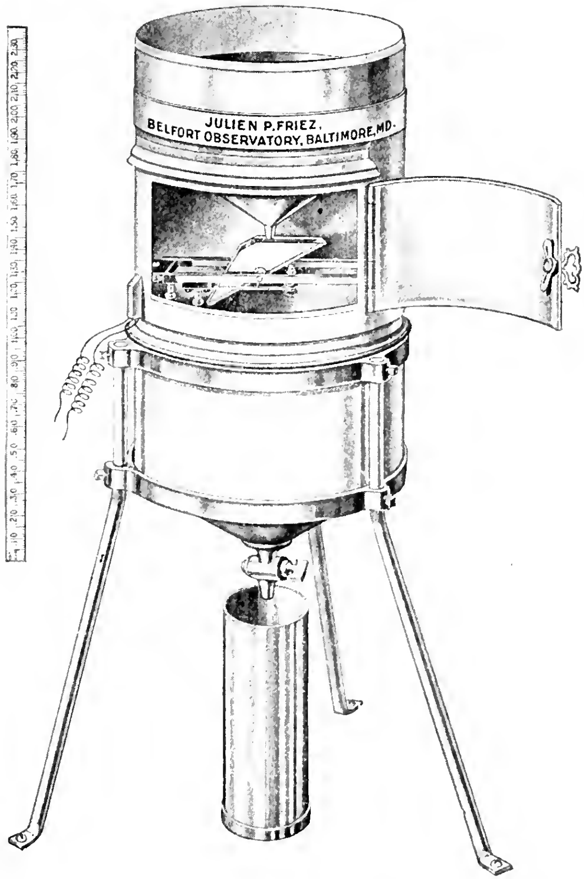


FIG. 7. FRIEZ TIPPING-BUCKET RAIN GAGE, COMPLETE.

small, only ½ in. per hour. Fig. 6 shows the chart used on this gage. The price of this instrument is $175.

By this instrument the precipitation is unnecessarily magnified, while the time-scale, as in the case of most of the instruments on the market, is too small for accurate determination of high rates of rainfall. The necessity of placing the collector upon the roof of the building, or else constructing a vault for the recorder, is also objectionable.

A recent improvement of the old type of Draper gage, devised by George A. Carpenter, city engineer of Pawtucket, makes

possible the exact determination of two minute intervals of time, and accordingly the maximum rates of precipitation for very short periods of time can be accurately determined. This result is accomplished by tapping the pen at intervals of two minutes in such a way as to make a dot heavier than the line traced by the pen and therefore readily distinguishable. Thus the amount of precipitation in each two minutes can be read from the chart with great accuracy. (See Fig. 32.)

3. *Friez Tipping Bucket Gage.* This is one of the most widely used of the automatic rain gages. It is made by Julien

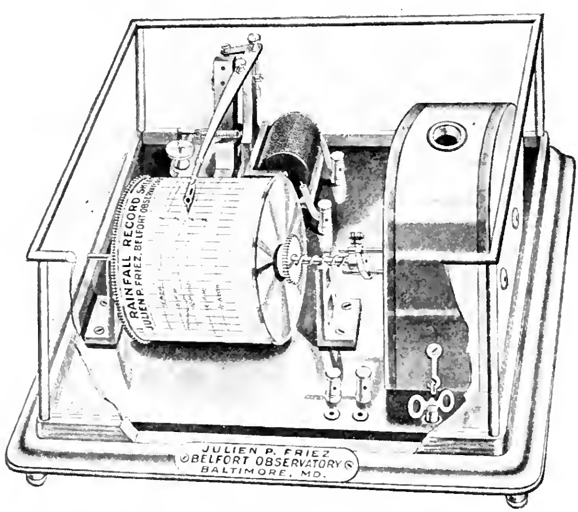


FIG. 8. RAINFALL REGISTER.

P. Friez of Baltimore, Md., and is illustrated in Figs. 7 and 8. The price of the instrument is $53.75 and of the recorder $65, making a total of $118.75. In this instrument rain is collected in a funnel 12 ins. in diameter and conducted through a tube into a bucket containing two compartments. The contents of each compartment are equivalent to .01 in. of rain. The bucket is supported on trunions in such a manner that as soon as a compartment is filled it tips and discharges the accumulated rain, presenting the other compartment for filling. Each time the bucket tips it makes an electrical contact and causes a pen to record a step upon a chart carried by a revolving cylin-

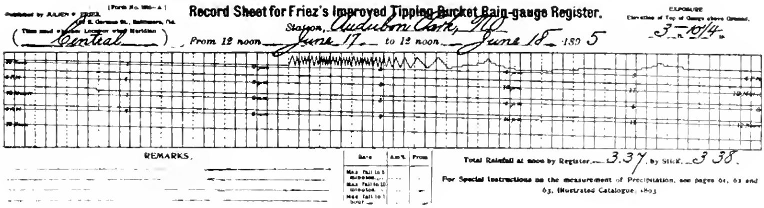


FIG. 9. ORIGINAL IS $10\frac{1}{4}$ INS. LONG.

der. A sample chart from this instrument is shown in Fig. 9. It is seen that the curve traced does not represent directly the progress of the storm, the motion of the pen being reciprocating, — up for .05 in. and down for .05 in.

The time scale of this chart is $2\frac{1}{2}$ ins. to an hour. The amount of rainfall is indicated, not by measurement on the chart, but by counting the number of steps, or of "flights" of ten steps each. It is therefore possible to determine the rates of rainfall from this record with a very good degree of precision. The possibilities of error are, however, considerable. The Weather Bureau carefully investigated the accuracy of the instrument and determined that on account of the appreciable time required for the bucket to tip, the error due to inflow of water into a compartment already full before the bucket could tip and present the empty compartment is sufficient to produce an error of about 5 per cent. at times of very heavy rain. It is found, also, that dirt washed into the buckets from the dust accumulating in the gage affects the character of the surfaces and the accuracy of the record. The adjustment of the instrument must be carefully made and its record is absolutely dependent upon the electrical apparatus working correctly.

A test of such a gage, made by J. B. F. Breed, chief engineer of the Commissioners of Sewerage of Louisville, Ky., showed a total discrepancy of 17 per cent. in a rainfall amounting to a total of 1.70 ins., with a maximum intensity of 7.68 ins. per hour for five minutes and an average intensity of 1.65 ins. for sixty minutes. By discharging water into the gage at various rates and measuring the actual accumulation as compared with the recorded collection, it was found that the rates of precipitation computed from the gage record should be increased by about 2 per cent. for each inch per hour. Thus a record showing precipitation at the rate of 5 ins. per hour should be corrected by adding 10 per cent., making the corrected rate 5.50 ins. per hour. The test was carried to an observed rate of 8.40 ins. per hour, the actual rate being 9.78 ins. per hour.

It has also been found that the bucket sometimes stops on center, thus failing to register entirely, as a portion of the water flows out each side and the bucket no longer tips.

4. *Queen Rain Gage.* This instrument, made by Queen-Gray Co., of 616 Chestnut Street, Philadelphia, Pa., is of the same pattern as the Friez tipping bucket gage. It is sold complete, with registering device, for $100. The recorder is somewhat smaller than that of the Friez gage so that the time scale is 2 ins. per hour instead of $2\frac{1}{2}$ ins., as in the Friez gage, and the movement of the pen for each .01 in. of rain is also somewhat less.

5. *Richard Rain Gage.* This instrument is made by Jules Richard of Paris and is sold in the United States by Ernest H. Du Vivier, 30 Church Street, New York City. It is made in two patterns, as shown in the accompanying illustrations, Figs. 10 and 11. Model A has a collector 8.3 ins. in diameter, the total height of the instrument being 57 ins. and its width 10.6 ins. The selling price in the United States is $78. The rain is accumulated in a reservoir connected through a weighing device with a pen recording upon a chart carried by a revolving cylinder. The height of the chart is 2.9 ins., which represents 0.4 in. of rain. When this amount has accumulated the reservoir is emptied by a siphon started by an electrical apparatus and the pen returns to zero ready to record the next filling of the reservoir. The length of the chart is 12 ins., which may be made to represent either one day or one week. The latter graduation is absolutely useless for recording maximum rates of rainfall, and even with the former the time scale would be but $\frac{1}{2}$ in. per hour, so that it would be impossible to measure short times with any degree of accuracy.

This instrument is open to the objection that the period during which the receiver is emptying may be considerable and thus introduce a material error. Moreover, the time scale is very short and the pen moves in a curved line, both of which are objectionable features.

Model B of the Richard gage contains a tipping bucket so designed that it tips gradually with increasing accumulations of water, and does not dump until 0.4 in. of rain has accumulated. The motion of the bucket is transmitted through a link to a pen marking, as in Model A, upon a chart of the same kind. This instrument has a collector 8.3 ins. in diameter and the total height of the instrument is 61 in. The maximum width is 13.8 ins. Its selling price is $171. The chart is the same as in Model A, and the time scale is too small for accurate determination of rate of precipitation. The motion of the pen being in a curved line is also objectionable, and the possibility

of errors in the transmission of the movement of the bucket to the pen are considerable. It is also subject in some degree to the same possibilities of error as the Friez gage.

Sample records from a Richard gage, used in Philadelphia, are appended. (Fig. 12.)

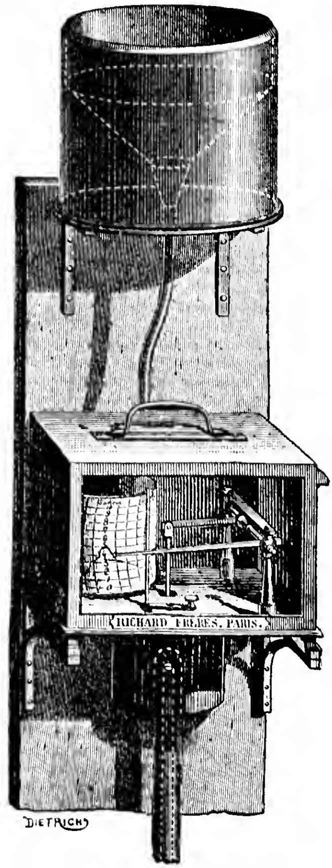
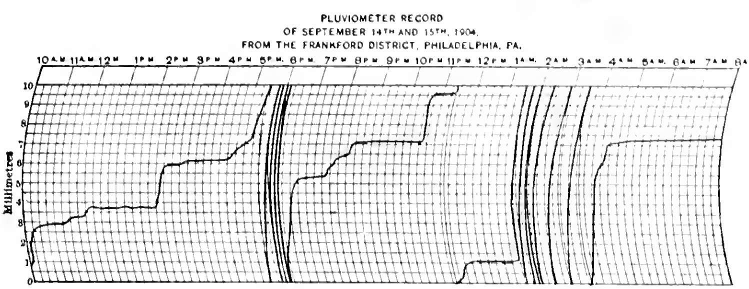


FIG. 10. RICHARD RAIN GAGE.

MODEL A. — The rain collected by the funnel runs into a metal receiver and causes an annular float connected with the pen arm to rise. The volume of the receiver is so calculated that the pen rises to the top of the recording cylinder for a rainfall 10 mm. or 0.4 ins. When the pen reaches the top of the cylinder it establishes an electric contact which operates an electro-magnet and starts a syphon; the receiver is emptied, the pen returns to zero, and is ready for the next ascension.

Approximate weight and dimensions:

		Inches.
Receiver —	Diameter	8.3
	Height	7.3
Recorder —	Length	10.0
	Height	8.5
	Width	6.7
Height of cylinder		5.1
Diameter of cylinder		3.7
Length of pen arm		5.5
Total height		57.0
Total width		10.6
Weight		31 lbs.



	Sept. 14th	Sept. 15th
Total Rainfall	2.30 inches.	2.30 inches.
Duration	14 hours.	6 hours.
Maximum rate per hour	4.14 in. for 20 min.	5.5 in. for 5 min.
Rainfall in 1 hour	1.60 inches.	1.57 inches.

FIG. 12. RECORD FROM A RICHARD RAIN GAGE.

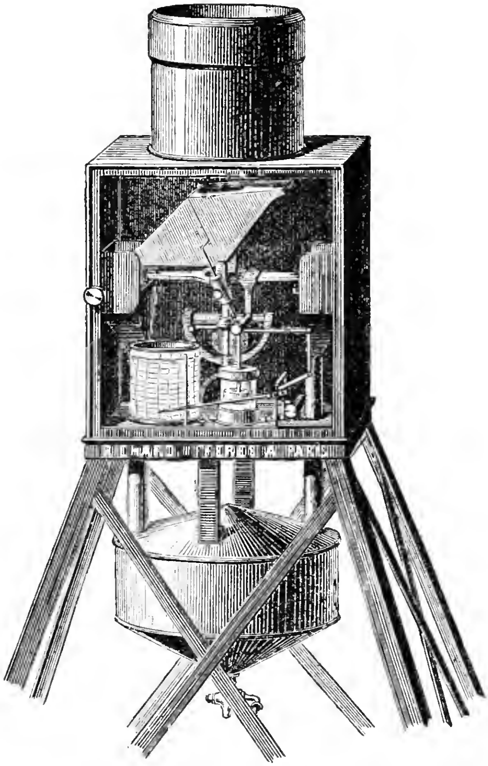


FIG. 11. RICHARD RAIN GAGE.

MODEL B. — The rain runs into a trough, forming part of a balance whose arm inclines according to the weight fallen.

When the pen reaches the top of the cylinder, the trough dumps, the balance returns to zero and the rain falling anew into a second trough, which has replaced the first, operates the balance again. The fall recorded is collected in a closed reservoir and may be measured with a graduated glass.

Approximate weight and dimensions:

		Inches.
Receiver —	Diameter	8.3
	Height	7.3
Recorder —	Length	13.8
	Height	16.3
	Width	13.8
Height of cylinder		5.1
Diameter of cylinder		3.7
Length of pen arm		5.5
Total height		61.0
Total height stand		47.0

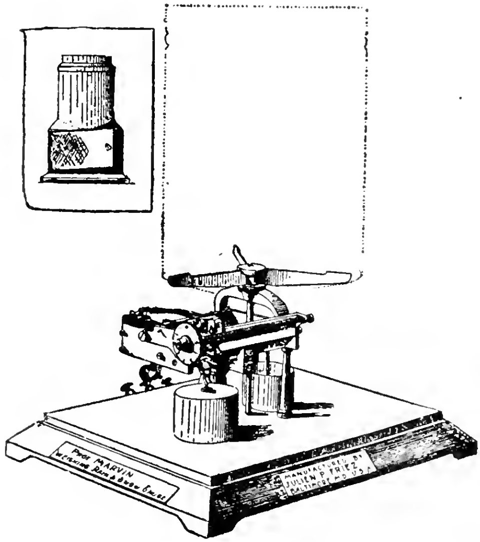


FIG. 13. MARVIN WEIGHING GAGE.

5. *Marvin Gage.* This is a very elaborate gage of the weighing type, devised by Prof. C. F. Marvin of the United States Weather Bureau, and constructed by Julien P. Friez, of Baltimore. It is used at only a few of the most important Weather Bureau stations. It is described in detail and illustrated in Circular E, Instrument Room, United States Weather Bureau, first edition, 1893. Cuts of the instrument and a sample chart are shown in Figs. 13, 14 and 15. The precipita-

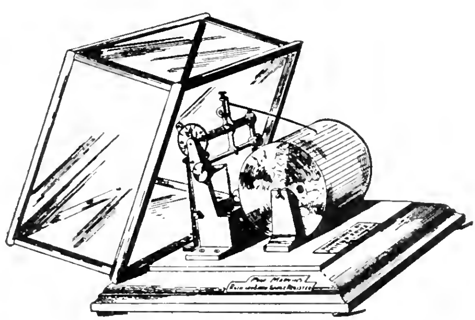


FIG. 14. REGISTER FOR MARVIN RAIN GAGE.

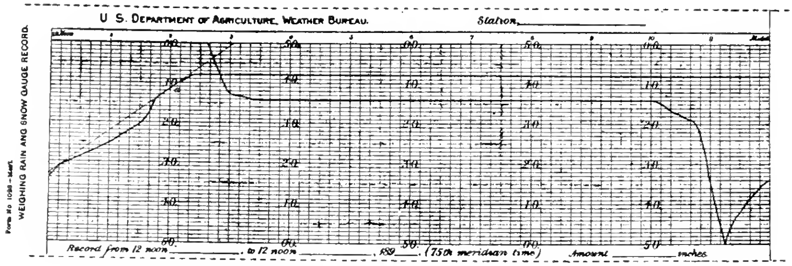


FIG. 15. ORIGINAL IS $8\frac{1}{4}$ INS. LONG.

tion is received and retained in a pan supported on a scale beam. Deflection of this beam makes an electrical contact, causing a record, and also a movement of the counterweight to again balance the beam. This record is made for each one-thousandth of an inch of rain. The pen moves back and forth across the record sheet, which is nearly $3\frac{1}{2}$ ins. wide, the entire motion in one direction corresponding to 1 in. of rain, so that the depth collected is magnified nearly seven times. The time scale, however, is comparatively small, — only 1 in. per hour, — but intervals of time as short as one minute can be determined, so that it is possible to determine rates of precipitation with a very good degree of accuracy.

The receiving part of the instrument is of comparatively small size and can be set upon the ground.

The principal disadvantages of this gage outside of the very considerable expense are the delicate mechanisms and electrical contacts to be kept in order. This gage is only made upon special order.

6. *FitzGerald Gage.* This gage was devised in 1878 by Mr. Desmond FitzGerald, and was described by him in *Engineering News* of May 31, 1884. An illustration of the gage and sample of the records are shown in Figs. 16 and 17.

In this gage the rain is collected in a funnel 14.85 ins. in diameter, and conducted through a tube into a receiver containing a float. The diameter of the receiver is such that 1 in. of rain causes the float to rise 2 ins. The float carries a pencil bearing directly upon the chart carried by a revolving cylinder. This cylinder is of such a size that a chart 24 ins. long is revolved once every day so that the time scale is 1 in. per hour. It is therefore possible to determine rates of precipitation with great accuracy.

This instrument has never been put upon the market, but it has been used by the Boston and Metropolitan Water Works

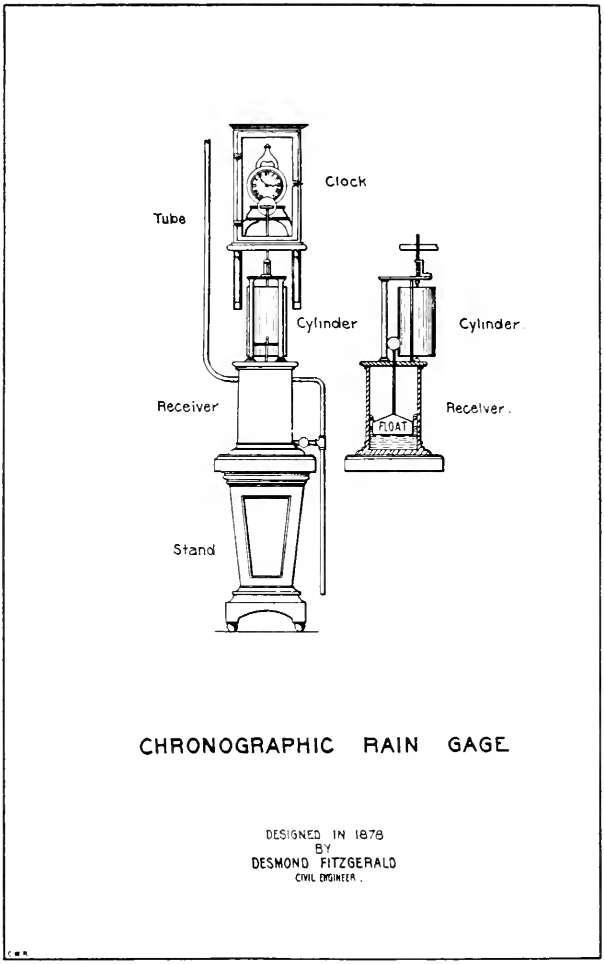


FIG. 16.

at Chestnut Hill Reservoir, and the Engineer Department of the District of Columbia.*

The principal disadvantage of this type of gage is that its collector must be placed upon the roof of a building, or else a chamber partly underground must be constructed to contain

* The Builders Iron Foundry of Providence, R. I., is preparing designs for a gage of the FitzGerald type, which it is expected will be sold for about $100.

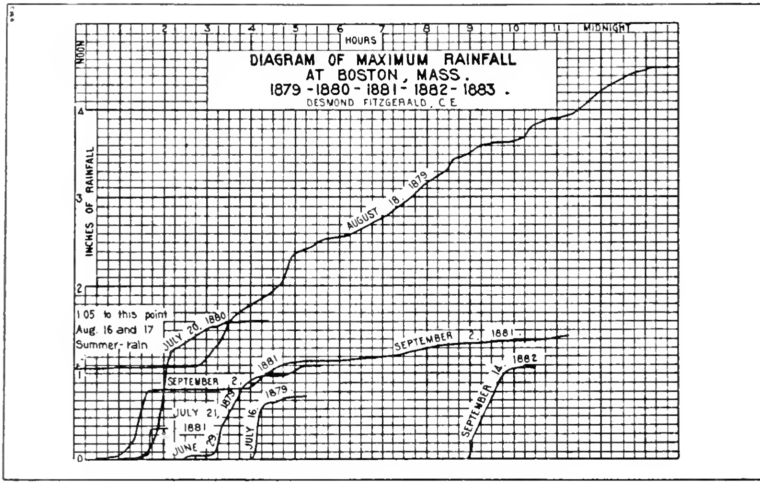


FIG. 17. ORIGINAL IS 13¼ INS. LONG.

the receiver and cylinder. It has the great advantages that it requires no electrical apparatus, and no mechanical motions other than the clockwork.

7. *Hellman Gage.* This type of recording rain gage is commonly used in Germany and in other parts of Europe. It is illustrated and briefly described in Frühling's " Entwässerung der Städte." This gage is similar to the FitzGerald gage in that the recording pen is carried directly by an arm connected with a float in the reservoir, and makes its record upon a revolving cylinder. It differs in the small size of the reservoir and drum, the former making necessary some appliance for emptying the receiver for comparatively small accumulations of water. In this gage a siphon is provided, by which the receiver is emptied into a can below, the contents of which can afterwards be measured. Judging from the illustration, the precipitation scale is magnified four or five times, and the time scale must be very small, — not over ½ in. per hour, — so that the chart record is obviously defective. This gage has the further objection that whatever rain falls while the receiver is being siphoned is not suitably recorded, and serious errors may be introduced from this source.

MEASUREMENT OF RUN-OFF.

A measurement of the actual volume of storm water run-off in sewers is not usually practicable. Weirs installed in the

sewers themselves are objectionable on the score of the head required and also because they cause a retardation of velocity and retention of sediment; it is also difficult to arrange weirs which shall give satisfactory results under wide variations of flow, and frequently with high velocities of approach. Venturi meters are expensive if furnished with recorders, which are indispensable in studies of storm flow; they have an insufficient range for measuring the wide fluctuations which are likely to occur; and as they must usually be set in inverted siphons in order to register properly, their installation in sewers already built involves some difficulties. Current meters for continuously recording the flow of sewage are not ordinarily practicable on account of the foreign material in the sewage, which is likely to clog the meter, or otherwise derange it. As a result, gagings, so-called, of storm-water flows in sewers, have almost invariably been made by recording the level of the sewage flowing and computing the quantity of flow, using Kutter's formula, usually with an assumed coefficient of roughness. In order to compute the flow in the sewer from observations of this kind, it is necessary to know the cross-section of the flowing stream, the slope, and the coefficient of roughness. The former can be readily computed from the known or measured cross-section of the sewer, having given the elevation of the surface of the sewage, which is easily obtained from a record of the water level or flow gage. In most observations of this character, the hydraulic slope has been assumed as parallel to the invert of the sewer, and a coefficient of roughness, n in Kutter's formula, has been assumed. In many cases these assumptions have probably been wide of the truth.

With regard to the hydraulic grade, the following comments by W. W. Horner, principal assistant engineer, Sewer Department, St. Louis, in a discussion of a paper by S. A. Greeley, in *Journal of the Western Society of Engineers* for September, 1913, are pertinent:

". . . It has been noted that there are marked differences between the grade of the sewer and the water surface grade. For example, in a 9-ft. sewer for one rain a depth of flow, at one point, of $4\frac{1}{2}$ ft. was observed; 1 000 ft. downstream

the depth was less than 4 ft. though several tributaries entered between, while 500 ft. farther downstream, the depth was over 5 ft. Similar variations have been noted in other rains. The sewer is uniform as to grade, size and condition. The most reasonable explanation of these differences is that the flow at the upper and lower gages is disturbed, in the case of the upper gage, by a curve 200 ft. upstream, and of the lower by a 3-ft. lateral, discharging into the main sewer nearly at right angles, 100 ft. above the gage. In both cases the velocities would be materially reduced from that computed by Kutter's formula. In another case, a sharp reverse curve and small local obstruction has been found to create a back pressure above of over 10 ft., although the sewer below was only slightly overcharged."

Other observers have had similar experiences. It is, therefore, evident that the use of the grade of the sewer as representing the hydraulic grade may result in serious errors in computing the actual flow in the sewer. It is obvious that correctly to compute this slope two or more water level indicators are necessary, and these must be exactly synchronized so that the true hydraulic slope corresponding to the depth at any time can be properly computed. The use of maximum flow gages, indicating merely the maximum height reached by the flood wave at any point, for the purpose of determining the hydraulic slope, is not to be commended, although such gages serve as a valuable check upon the readings of the automatic gages. The crest of the flood wave progressing downstream leaves its record on each of these gages, but it is obvious that the hydraulic slope is not the slope between the highest point reached at one gage and the highest point reached at the succeeding gage, since the crest of the flood was not at both of these points at the same time.

Wide errors may also be introduced into the estimate of flow by incorrect assumption of the value of the coefficient. It is only necessary to call attention to the fact that the values of n in Kutter's formula for the classes of sewers ordinarily gaged may range from 0.009 to 0.017 in order to realize that assumptions of this coefficient may be far from the truth. These two values, as it happens, have been found by velocity measurements at Pawtucket and Philadelphia to apply to the particular

cases referred to; but it is evident that the assumption of such coefficients without experimental determination may introduce serious errors, possibly as much as 50 per cent. Obviously, this method of estimating flow can only be correctly employed when the coefficient is experimentally determined for the sewer under consideration. Either the coefficient of roughness n in Kutter's formula, or the coefficient C in the Hazen-Williams formula, may be determined and employed in the estimation of flow. It is not thought best to use the Chezy formula directly, since the coefficient in this formula would not be constant for varying depths in the sewer and the resulting changes in the hydraulic radius.

In the study of run-off at Pawtucket the following investigations were made in an endeavor to find the value for n in the Kutter formula for the sewer under investigation. The diameter of the sewer was too small to permit of the use of

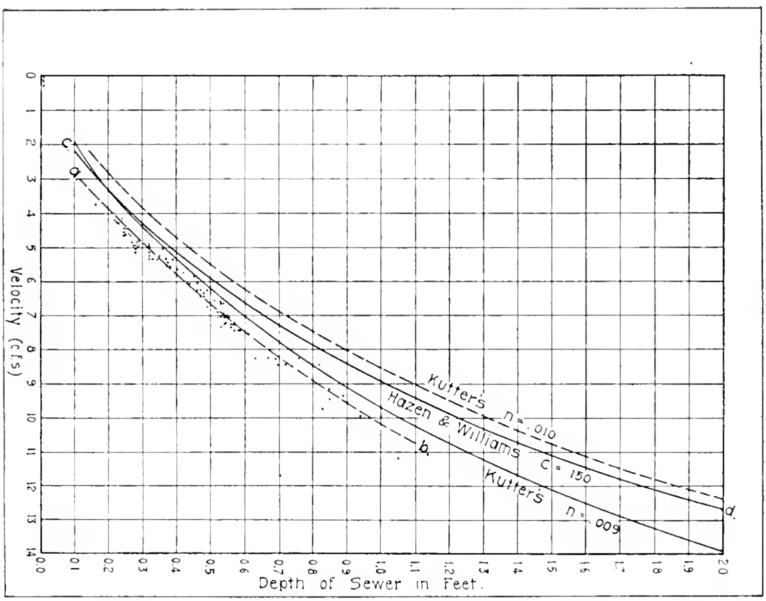


FIG. 18. — VELOCITY CURVES FOR THE ESTEN AVE. SEWER, BETWEEN MANHOLES 1 AND 2, AS OBTAINED FROM FLOAT MEASUREMENTS. D. = 52 INS. S. = 0.60 FT. PER 100. SURFACE IS CEMENT.

current meters when measuring storm flows. It is seldom that a depth greater than one foot is reached in this sewer, and most of the observations had to do with much lesser depths. (A description of this sewer will be found in subsequent pages.)

Because of these conditions, floats were tried between manholes 447 ft. apart. The surface slope of the discharge corresponded with the slope of the sewer, as nearly as it was practical to measure the depth of flow, and the slope of the sewer, .006, was therefore adopted for the value of s.

The floats used were pieces of wood three inches in diameter and two inches long, and the time taken for the passage of these between manholes was recorded by observers. About 170 observations were recorded, during storms occurring between February, 1905, and February, 1906, and from these data ninety-one velocities were figured for various depths of flow between 0.16 and 1.1 ft. These velocities have been plotted and a curve drawn which corresponds very closely to the curve of Kutter's formula when using a value for n of .0085. See Fig. 18.

As the velocity measured was the surface velocity, and therefore, for the shallow depths observed, was very nearly a maximum, it is fair to assume a somewhat lower figure for the average velocity. Mr. Fteley, in his measurements of the flow in the Sudbury River Conduit, found the average velocity there to be about 88 per cent. of the maximum velocity, and a velocity curve, *cd*, representing 88 per cent. of the observed velocity has been drawn.

This curve lies between the curves of the Kutter formula drawn with values for n of .010 and .009, but very close to the former curve. It is identical with the velocity curve of the Hazen and Williams formula when giving a value of 150 to c in that formula, $V = cr^{0.63} s^{0.54} 0.001^{-0.04}$.

With respect to this latter formula, it may be said that c has a range of 145 to 152 when compared with the experiments of Darcy and Bazin in semi-circular conduits of 4.1 ft. diameter, with a surface of pure cement.

The following quotation is taken from W. G. Taylor's article upon a New Main Intercepting Sewer at Waterbury,

Conn., which was published in the *Engineering Record* of April 4, 1908. "Observations upon the sewage flow in the main carrier, at depths up to the springing line, have shown that the value of n in Kutter's formula when applied to the sewer flow is not greater than 0.010." The sewer for which these values were obtained was of reinforced concrete of horseshoe shape, 5 ft. 6 in. x 4 ft. 5 in. Great care was used in churning the deposited concrete, and the interior and exterior surfaces are reported as being "very smooth."

Types of Recording Gages. Leaving Venturi and current meters out of consideration, practically the only type of automatic gage applicable to gaging storm water flows in sewers is a gage of the water level recorder type. All of the gages available for this purpose may be divided into two general classes, — float gages and pneumatic pressure gages. Either class is equally applicable to keeping a continuous record of the head of water over a weir in case it is practicable to use a weir for accurate measurements of flow.

In order to secure proper registration with any type of gage, it is practically essential to install the float or pressure chamber in a separate manhole connected with the sewer, rather than in the sewer itself. This adds materially to the cost of installing the gage and keeping records of sewer flow, but it has not been found practicable to obtain trustworthy records by means of a gage installed directly in the sewer itself.

Float Gages. In this type of gage a float contained within a pipe or other suitable guide is connected with a recording apparatus through the medium of a cord, chain, tape or by a solid rod or tube.

**The Hydro-Chronograph*, made by the Hydro Manufacturing Company of Philadelphia, consists of a float and a recorder. The float is connected by a chain with a sprocket wheel at the recorder. The motion of the float is thus transmitted, on a reduced scale, to a pen moving in front of a vertical recording drum, which is rotated monthly, weekly, or daily, as desired. The diameter of the cylinder is such that a time scale of about 1 in. per hour may be employed.

* The following descriptions of recording gages have been quoted from the manuscript of a forthcoming "Handbook of American Sewerage Practice," by Leonard Metcalf and Harrison P. Eddy.

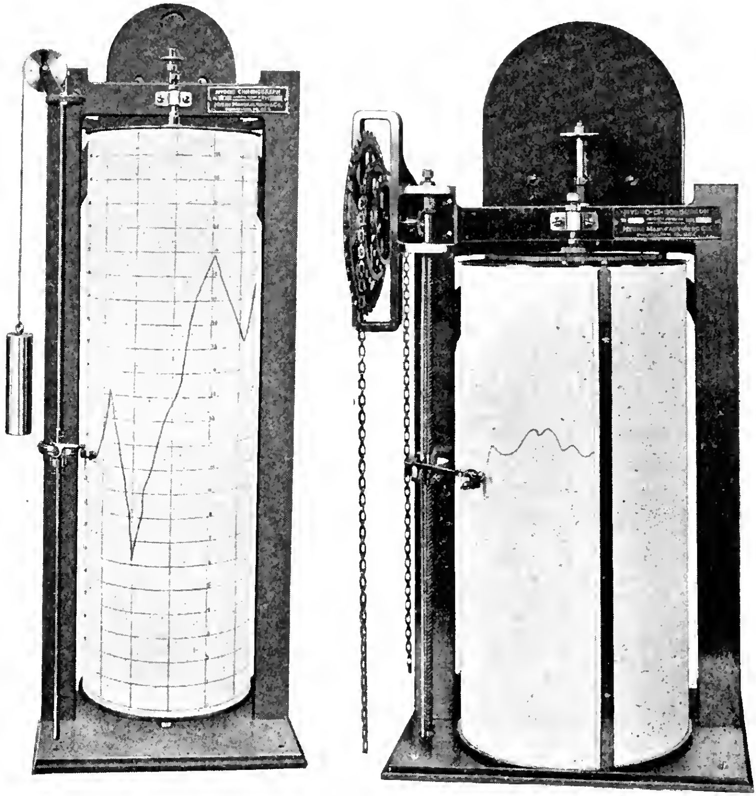


FIG. 19. — HYDRO-CHRONOGRAPH.

The cylinder is 8 ins. long and 12 ins. in circumference. The clock can be arranged to drive the pen the length of the cylinder once a week or once a day. In the latter case, the time scale would be $\frac{1}{3}$ in. to the hour, and this is the largest scale for which the instrument is regularly made. Sprocket wheels are provided for different ranges in height of water, as follows:

Range of Water Level.	Total Width (Circumference of Chart).	Scale of Heights.
1 ft.	1 ft.	1 ft. to 1 ft.
5 ft.	1 ft.	0.2 ft. to 1 ft.
10 ft.	1 ft.	0.1 ft. to 1 ft.
15 ft.	1 ft.	0.0667 ft. to 1 ft.
20 ft.	1 ft.	0.05 ft. to 1 ft.

List prices of these instruments range from $115 to $150.

The amount of reduction in vertical scale will depend upon the range of motion of the float. This company manufactures a weir gage in which the fluctuations of water level are recorded without reduction; but this can be employed only for a range of about 2 ft. For large sewers it is impracticable to use a drum long enough to cover the range of elevation, without reduction. The list prices of these instruments range from $100 to about $200.

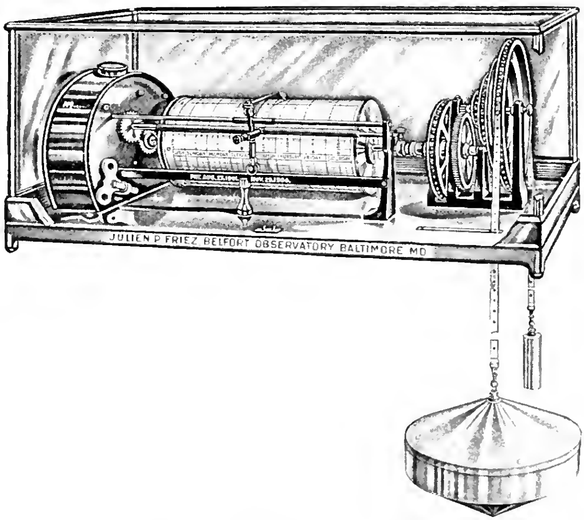


FIG. 20. FRIEZ IMPROVED AUTOMATIC WATER STAGE REGISTER.

Friez's Improved Automatic Water Stage Register. This instrument is made by Julien P. Friez of Baltimore. As shown by the illustration, Fig. 20, motion of the float causes the drum to rotate, while the pen is caused to move parallel to the axis of the drum by means of clockwork.

Builders Iron Foundry Water Level Recorder. (Fig. 21.) In this gage the cord from the float moves an arm carrying a pen in front of a circular chart, which is rotated by clockwork, The pen accordingly moves in a circular arc, and the time scale varies with the position of the pen. The instrument is enclosed in a cast-iron box mounted upon a hollow standard through which the float cord passes. It is made in two sizes, having 8-in. and 12-in. dials, and the prices are $75 and $90, respectively; or they can be obtained with an iron outer door for five dollars additional.

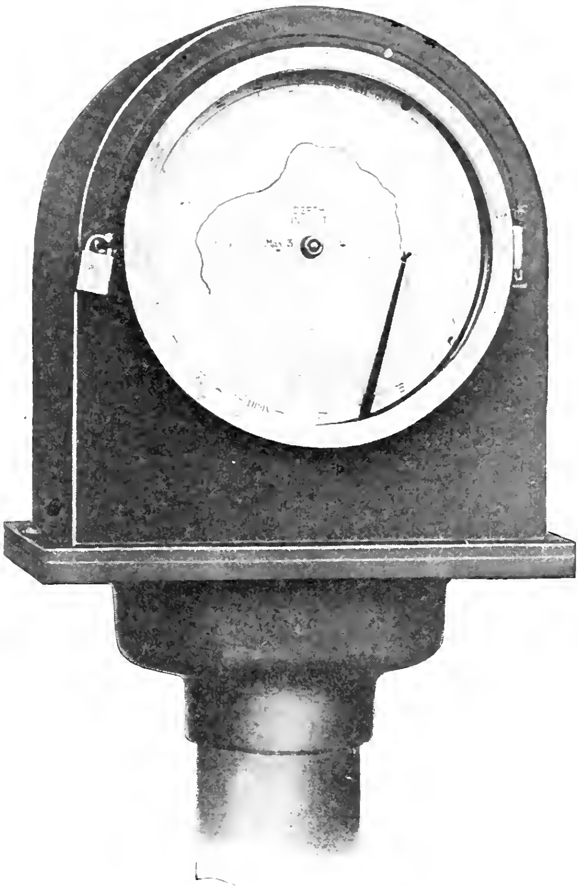


FIG. 21. WATER LEVEL RECORDER, BUILDERS IRON FOUNDRY.

Obviously, with this gage, the scale of heights as recorded upon the chart will depend upon the range to be covered and the size of the chart. A rectangular chart is not necessary for records of this kind, and the only disadvantage of this form of record is that the time-scale is unduly small when the pen is in its lowest position.

Builders Iron Foundry has also in some cases constructed a modification of the recording instrument of the Venturi meter for use with a float, to indicate and record directly the rate of

flow over a weir, and also to integrate these rates and show on a recorder the total quantity passed.

Pneumatic Pressure Gages. In these gages a diaphragm box or pressure chamber is immersed in the liquid, and the changes in pressure resulting from rising or falling surface are transmitted through a small pneumatic tube to a recording apparatus located at any convenient point.

Diaphragm Gage. The illustrations, Figs. 22 and 23, show this instrument, which is well known and widely used. It is made for either 8-in. or 12-in. charts, and the prices range from \$55 to \$80, including 25 ft. of connecting tubing. These instruments are made by the Bristol Company of Waterbury, Conn., and by the Industrial Instrument Co., of Foxboro, Mass.

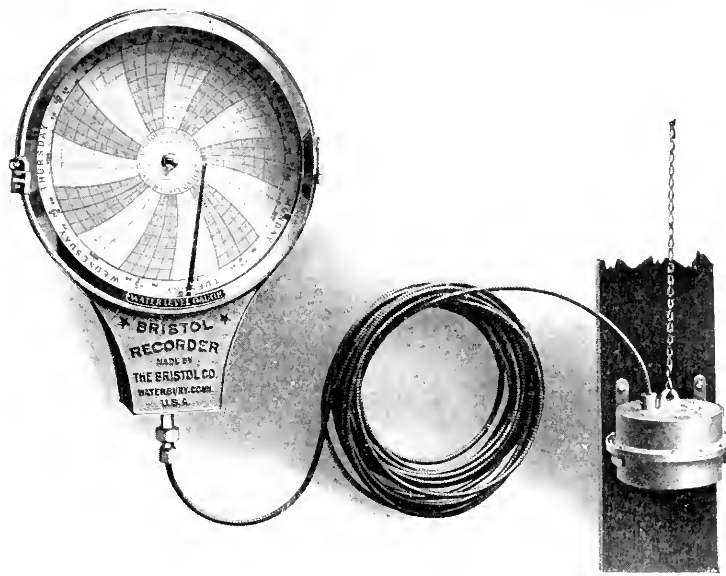


FIG. 22.

The recording instrument shown above is with a seven-day chart. The dark sections of chart represent the night periods.

The flexible connecting tube is here shown protected with flexible copper armor.

The sensitive bulb may be screwed or bolted to a vertical plank.

Sanborn Flow Recorder. (Fig. 24.) For sewers, the recorder may be placed in a manhole, at the sidewalk, or in a nearby building. One-fourth inch copper tubing connects

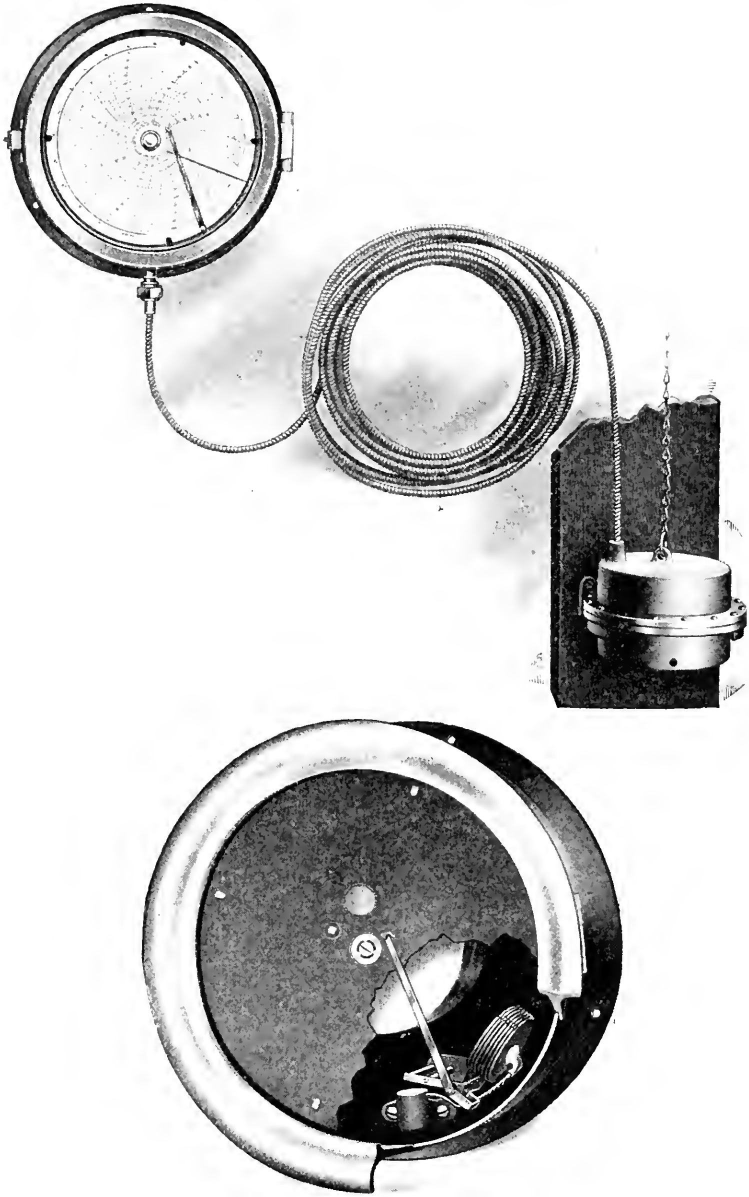


FIG. 23. FOXBORO GAGE.

from the recorder to the inlet at the sewer where is located a "compensator," which is a special form of diving-bell. It resembles a piece of tubing, one and one-half inches in diameter, varying in length from a few inches for small sewers to three feet for twenty-foot sewers; it is placed slanting, on an angle of 45 degrees with the vertical, in the direction of flow, and extends to within a few inches of the bottom of the sewer. This compensator is constructed smooth outside and inside so that sewage is not apt to collect. The inlet is at the very bottom. Claims made for this device are, that no float is required, no diaphragm at the inlet, the pressure medium is air and will not freeze, and the recorder may be placed in any convenient location.

The price complete with compensator and twenty-five feet of tubing is $75. It is made by the American Steam Gauge and Valve Mfg. Co., Boston.

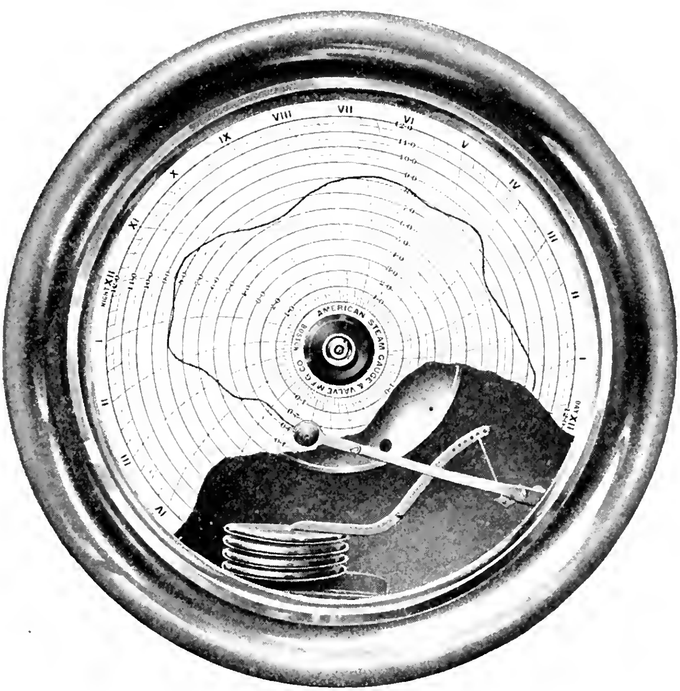


FIG. 24. SANBORN FLOW RECORDER.

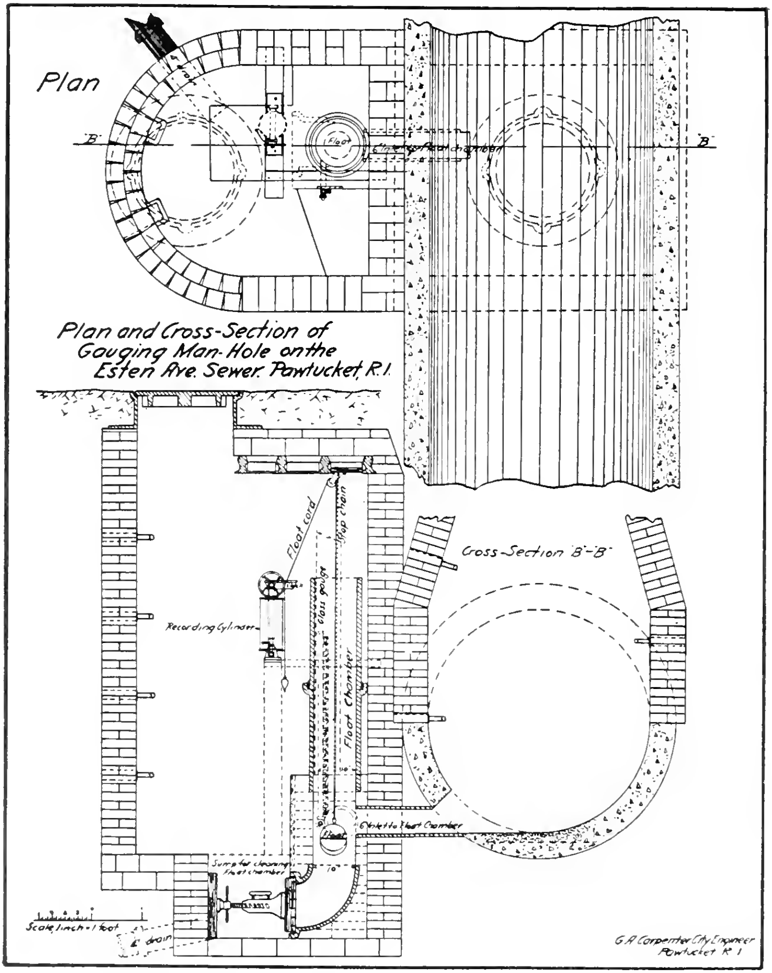


FIG. 25.

Installation of Automatic Sewer Gage. A reliable automatic record of the depth of the storm flow in the sewer is of equal importance with the record of the rate of precipitation, but is even more difficult to obtain. So many difficulties beset the installation of an accessible recording device that it has been

very hard to obtain the coöperation of municipal engineers in this work. In sewers less than four feet in diameter and in any sewer where the normal dry-weather flow is of very shallow depth, the installation of a recording device in the sewer itself is apt to produce such an obstruction to the flow as will set up artificial conditions, which make a record of the correct depth of flow impossible.

It is therefore much better to construct an auxiliary manhole, independent of the sewer, for the special purpose of installing the recording mechanism. Such a manhole is shown in Fig. 25. In this manhole a float chamber can be constructed and connected with the main sewer by a small pipe, or pipes, and these need be the only connection with the sewer. Under such a construction it will be possible to visit and inspect the recording mechanism without the inconvenience attendant upon a descent into a regular manhole which is a part of the sewer itself. It will still have the disagreeable feature, however, of being below ground and accessible only through an opening in the street surface. A much better location for the recording device is at the edge of the curb and above the level of the sidewalk. This can be accomplished through a construction similar to a police signal box or as illustrated in Fig. 30, and the chart will thus be made readily accessible. The only criticism of such a method of installation lies in the necessity of providing some method of accurately checking the chart record with the depth of flow.

Particular care should be taken in connecting the gaging chamber or float chamber with the sewer, to see that the connecting pipe is normal to the direction of flow, and does not project into the sewer. If this precaution is not observed, the recorded heights will be in error — too high if the connecting pipe is directed upstream or against the current, and too low if in the reverse direction. The precautions taken should be the same as in installing a piezometer connection to a water pipe.

It is highly necessary that recording devices be regularly inspected in order that they may be sure to be in operation when most needed, and the more accessible and convenient it is possible to make their location, the more careful attention

will they receive. Maximum rates of precipitation and the attendant depth of flow in the sewer are of infrequent occurrence, and it is very essential that the recording device be in operation whenever such a discharge takes place.

Maximum Flow Gages. Practically the only information to be obtained from a maximum flow gage is the greatest height reached by the flood wave at the point of observation since the

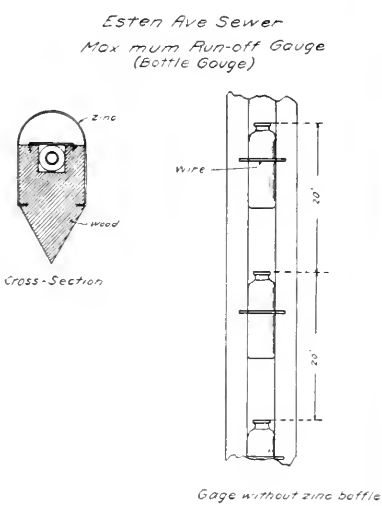


FIG. 26.

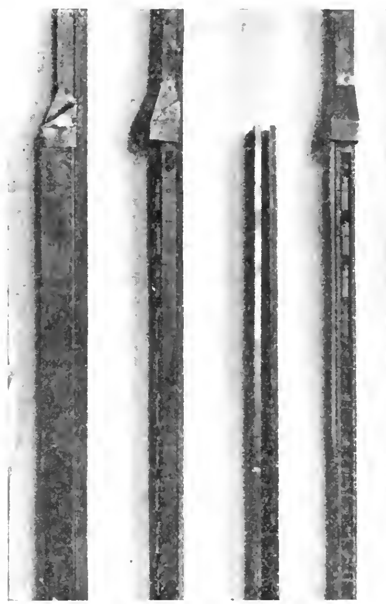


FIG. 27. GAGE ROD.

last recorded measurement. Ordinarily the records thus obtained are of little value, but they may occasionally serve as a valuable check upon the records of an automatic gage which may be out of order and fail to indicate the highest point reached by the flood. It is, therefore, advisable to install such maximum flow gages at all points where automatic water level recorders are installed.

In the earlier observations of run-off in sewers, the maximum gages consisted merely of whitewashed laths set firmly

in position in manholes, the expectation being that the highest point reached by the sewage would be clearly indicated on the whitewash. In some cases this simple type of gage has proven satisfactory, although in many cases the whitewash has peeled off above the height to which the sewage reached, and in other cases, for some unexplained reason, the maximum height could not be distinguished upon the gage. The most satisfactory type thus far devised consists of a rod to which are firmly fastened a number of small vials having their mouths set at uniform distances apart, usually one tenth or two tenths of a foot, the whole being properly protected from the flowing current by a shield or perforated tube. On examining this rod, it is evident that the sewage must have been as high as the highest vial which is found to be filled with water. Inverting the rod and emptying the vials is all that is necessary to prepare the gage for use. This type of gage, as used at Pawtucket, R. I., is shown in Figs. 26 and 27. It is best located in a manhole, with the bottom of the gage slightly above the normal dry-weather flow.

In some cases, gages of this type have not proved satisfactory where high velocities have obtained, — such as 8 ft. per second.

Actual Measurements of Storm-Water Flow.

Your committee submits herewith, in tabular form, all available records of storm-water flows in sewers, including not only those which have been made in coöperation with this committee and submitted to it for publication, but all other published records of storm sewer gagings which have come to its attention.

All of these records are open to serious criticism, and their value as accurate measurements of run-off is not very great. Nevertheless, they are the only records available, and a careful study of them will offer many suggestions as to method of improving the details of further studies, and will also furnish the best and in fact the only information available relating to the determination of coefficients of run-off or ratio between flows in storm water sewers and rainfall.

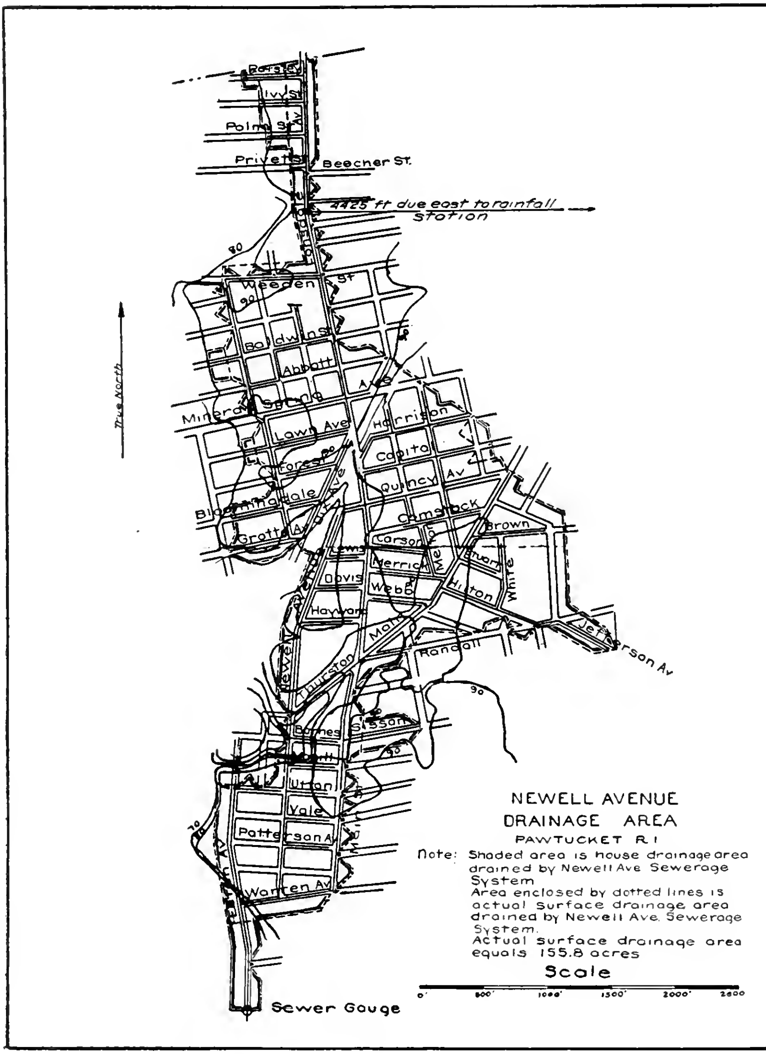


FIG. 28.

As illustrative of the observations required and the computations to be made in a comparison of rainfall, we submit the following details of the work done at Pawtucket, R. I.

Study of Rainfall and Run-Off at Pawtucket, R. I. The study of rainfall and run-off which has been made at Pawtucket, R. I., was in a typical, middle-class tenement section in the west central part of the city. A plan of the catchment area is shown in Fig. 28. It has a fairly regular longitudinal slope of 1.69 per 100, and the maximum length of sewer contributing to the run-off measuring station is 1.64 miles, giving a time of flow in the sewers of about twenty-four minutes, and a time of concentration of about thirty minutes. Data relating to the drainage area are given below.

The main outlet sewer, in which the measurements were made, is built of concrete, circular in section and 52 ins. in diameter. Steel forms were used in its construction and the interior surface is very smooth. A bottom strip about two feet in width was made of rich Portland cement mortar, placed and troweled by hand after the forms were withdrawn.

DATA RELATIVE TO THE NEWELL AVENUE DRAINAGE AREA, LOCATED IN PAWTUCKET, R. I., AS NOTED JUNE, 1910.

SECTION OF DRAIN.

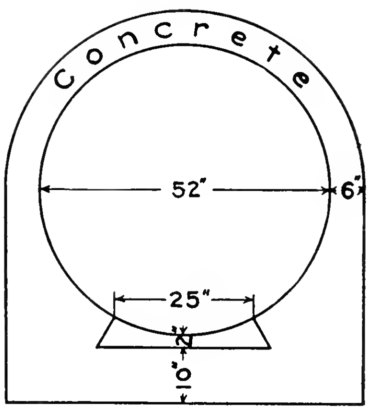


FIG. 29.

Rate of grade in ft. per 100 from point of observation, toward mouth of sewer = 0.60.

Rate of grade in ft. per 100 from point of observation up sewer = 0.90.

Rate of grade changes to 4.70 ft. per 100, 447 ft. below point of observation.

Size of channel changes to 48 in., 2 250 ft. above point of observation.
No change in size of channel to outlet 545 ft. below point of observation.
Area contributing to flow, 146 acres.

IMPERVIOUS AREA.

Area of paved streets including macadam	36 acres.
Area of houses with roofs connected, or discharging on an impervious area	14 acres.
Total	50 acres.

PERVIOUS AREAS.

Area of developed land	96 acres.
Character of soil, sand and gravel covered with 2 ft. ± of yellow loam	..
Total	96 acres.
Total area as above	146 acres.

Average longitudinal slopes of drainage area, —
2.0 ft. per 100 for 1 800 ft.
3.3 ft. per 100 for 600 ft.
0.90 ft. per 100 for 2 900 ft.
0.70 ft. per 100 for 600 ft.
0.50 ft. per 100 for 1 700 ft.
Average transverse slopes of drainage area, —
1.5 ft. per 100 for 800 ft.
0.9 ft. per 100 for 800 ft.
1.9 ft. per 100 for 2 600 ft.
0.9 ft. per 100 for 800 ft.
Method of computing discharge, Williams and Hazen formula,*

$$V = CR^{0.63}S^{0.54}0.001^{-0.04}.$$

Slope of water surface at point of observation, called 0.60 ft. per 100.
Remarks. — This formula gives results about 94 per cent. of the Kutter formula when using $n = .009$ in that formula.

A 12-in. iron pipe shown in Fig. 30 carries the dry-weather flow to the disposal works. This pipe was shut off during the periods covered by the following records, thus turning the whole flow from the area through the 52-in. sewer.

Details of the manhole containing the recording apparatus are shown in Fig. 25, and a maximum gage similar in construction to that shown in Figs. 26 and 27 was used in the main

* $C = 150$.

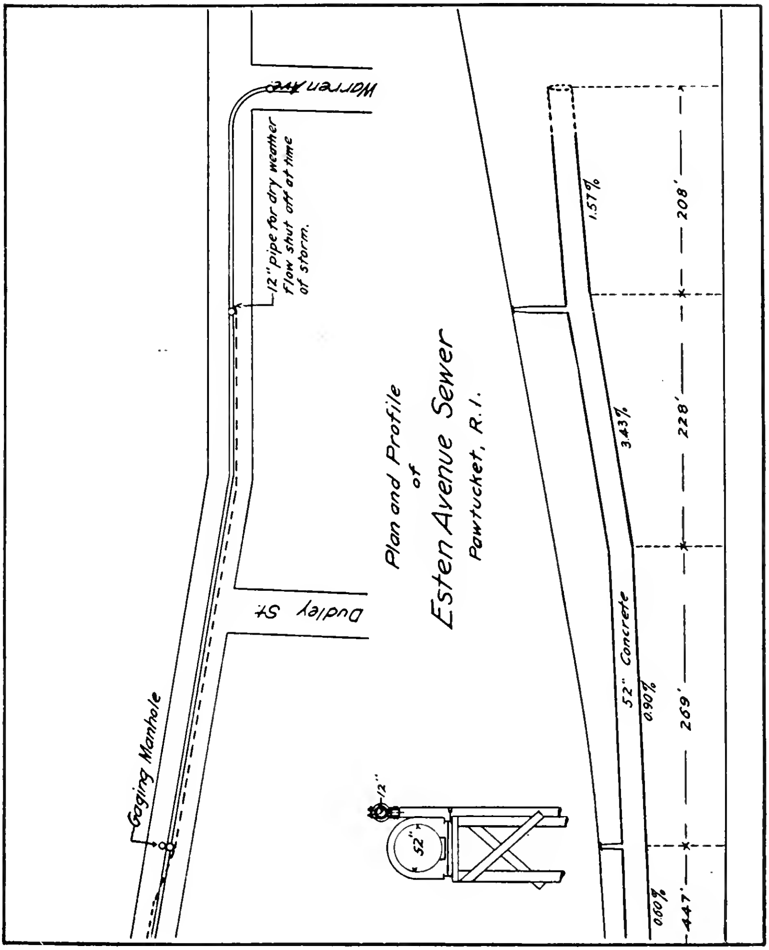


FIG. 30.

sewer opposite the gaging manhole. A water column in the gaging manhole was used to check the automatic gage whenever possible.

The automatic rain gage is of the Draper type (old pattern), producing a chart illustrated in Fig. 31. It originally gave a seven days' record on the same length of chart shown on the

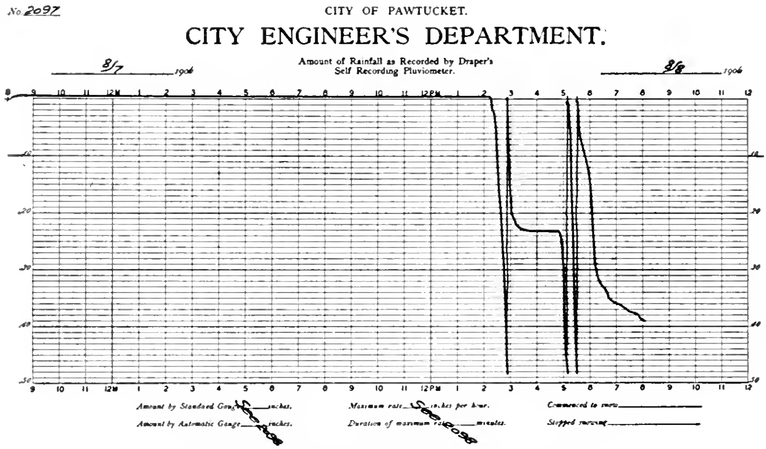


FIG. 31. ORIGINAL CHART $9\frac{1}{4}$ INS. LONG.

above plates, but was changed long before the date of these observations and made to show a twenty-four-hour record on the same length of chart. By this extended hour interval it is possible to read more closely the rates of precipitation, but even with this chart the irregularities of precipitation rates are so great and varied that they are difficult of interpretation,

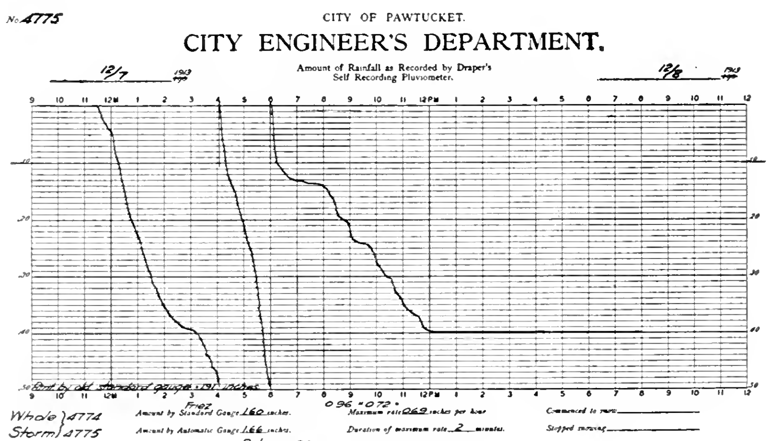


FIG. 32.

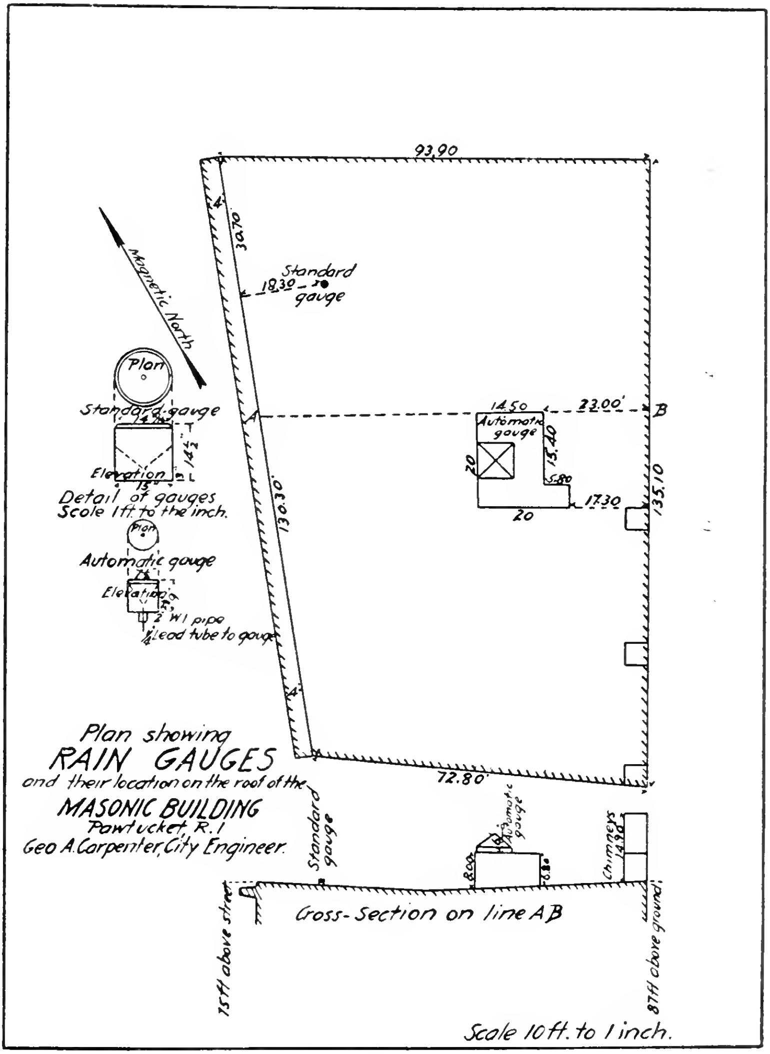


FIG. 33.

and it is very doubtful whether two persons would interpret these rainfall curves exactly the same.

Since these records were taken an attachment has been

added to the rain gage which produces a visible mark on the chart at intervals of two minutes. A copy of the precipitation records now produced by this instrument is shown in Fig. 32. Counting the hundredths of an inch of rainfall between any two of these marks and multiplying by 30 will at once give the rate in inches per hour for a duration of two minutes, and so on for any interval of time desired.

Although the rain gage is located outside of the Newell Avenue drainage area, as indicated in Fig. 28 and as shown in detail in Fig. 33, yet it is believed, from observations of total precipitation made both within and without the drainage area, that the records used fairly represent the precipitation on the drainage area itself.

It has been found by repeated observations that the automatic gage records about 83 per cent. of the rainfall collected by the standard gage, and each record of the automatic gage which has been used in this report has been corrected by applying this factor.

Observations of the flow in the Esten Avenue sewer, and of the accompanying rainfall, have been carried on for seven years, but in the records of the 132 storms which have been obtained and analyzed during that period, nearly 60 per cent. have been found to contain nothing of especial interest or value. They are mostly storms of such low rates of precipitation that the records shed little light upon the subject under consideration.

In about 15 per cent. of the observations either the rainfall or the run-off records, generally the latter, were found to be unsatisfactory, due to local complications; failure of chart to properly record; failure of the several sets of observations to properly check each other; existence of snow on the ground; and many other reasons ascertainable only after repeated experiments with this kind of work.

It therefore obtains, that after a period of seven years of observation, only 36 of the recorded storms, or 27 per cent., have been accepted for study. The study of one of these 36 records is here reproduced, upon the form of chart devised by the committee for presentation of such records. (Fig. 34.) The summary of all gagings of storms in which the rainfall

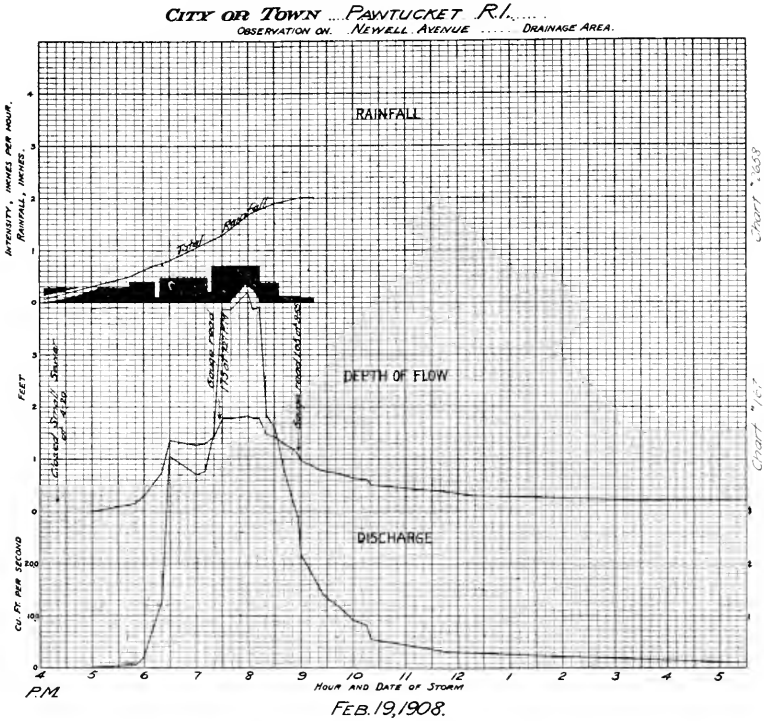


FIG. 34.

producing the flood flow had a duration of twenty-five minutes or more, will be found on a subsequent page.

The winter storm of February 19, 1908, of which particularly good records were obtained, has been placed in the table of typical storms despite the fact that the storm was a mixture of snow and rain and that when the storm ceased there was about a half an inch of snow on the ground. There was no snow on the ground at the beginning of the storm. The maximum rate of precipitation of this storm was 0.70 in. per hour and its duration fifty-four minutes.

This detailed description of apparatus and methods used, together with the reproduction of the chart and curves, have been given in order that engineers interested in further study of this subject may have placed before them as much of the

TABLE 1. — PAWTUCKET, R. I. COMPARISON OF RAINFALL AND RUN-OFF, YEARS 1906–1910.

Sheet Number.	Date.	Total Rainfall in Inches.	Duration in Hours and Minutes.	Total Rainfall in Cubic Feet per Acre.	Maximum Rate of Precipitation in Inches per Hour.	Duration of Maximum Rate in Minutes.	Total Discharge in Cubic Feet per Acre.	Duration of Discharge in Hours and Minutes.	Percentage of Total Rainfall reaching Sewer.	Rate of Precipitation preceding Flood Wave, Inches per Hour.	Duration of Rate, in Column 11 in Minutes.	Maximum Rate of Discharge in Cu. Ft. per Second per Acre.	Ratio of Maximum Discharge Rate to Preceding Precipitation Rate, expressed as Percentage. $\frac{\text{Col. 13 x 100}}{\text{Col. 11}}$.
1	2	3	4	5	6	7	8	9	10	11	12	13	14
29	August 26, 1908....	1.670	8–40	6 062	0.504	5	2 267	10–55	37.4	0.50	30	0.160	32.0 Summer
6	October 20, 1906....	2.110	8–15	7 660	1.020	35	2 424	13–10	31.7	1.02	35	0.302	29.6 Fall
22	February 19, 1908....	1.935	5–10	7 024	0.700	54	3 822	17–00	54.4	0.70	54	0.462	66.0 Winter

original data as possible and may thus be enabled to draw their own conclusions from the data obtained, as well as the method employed in analysis.

Rate of Precipitation Causing Maximum Flow. It is of the greatest importance in arriving at a correct conclusion that the maximum rate of flow in the sewer be compared with the rainfall which actually caused this run-off. It is, therefore, particularly important that the time required for concentration of run-off at the gaging point, under the conditions existing at the time when the gaging was made, be accurately known.

It is evident that if the time required for the concentration of the run-off at the gaging point is thirty minutes, the run-off factor obtained by comparing the maximum rate of run-off with the rate of rainfall which obtained for a period of five minutes or with the average rate which obtained for a period of sixty minutes, would be considerably in error, unless the rate were uniform in the latter case. The extent to which erroneous assumptions of the time of concentration may result in incorrect coefficients is indicated by the table computed from the Philadelphia gagings. (Table 23.)

In such comparisons it is evident that the actual time of concentration existing for the particular gaging is the figure desired, — not the computed time of concentration for maximum velocities of flow, which may be widely different from those existing. If the sewers are but partly filled and the velocity of flow is less than the maximum velocity, it is evident that the time of concentration will be considerably greater than the time computed upon the basis of maximum velocities.

Another point requiring careful consideration is the interpretation of the run-off from storms of less total duration, or having a downpour of less total duration, than the time of concentration for the drainage system gaged. This is particularly true in the case of large areas for which the time of concentration is considerable. It is not often that storms occur of sufficient uniform intensity to produce a noticeable "flood wave," and lasting from thirty to sixty or ninety minutes. Accordingly, storms which give significant information relating to drainage areas for which the time of concentration exceeds

thirty minutes are of rare occurrence, and records of value for such systems are obtainable only after a number of years of observation. Much valuable information could be obtained in shorter periods of time if sub-districts, for which the time of concentration would be short, were gaged. Your committee has spent a large amount of time in endeavoring to obtain significant information from storms in which the period of downpour was of less duration than the time of concentration of the district gaged, but has been forced to the conclusion that, with our present knowledge, no information of value can be obtained from such records. It seems impossible to estimate the area actually yielding storm water from a shower of less duration than the time of concentration. Take, for instance, the case of a heavy downpour lasting ten minutes upon a drainage area for which the time of concentration is thirty minutes. If the entire rainstorm lasts but ten minutes, it is evident that the maximum rate of run-off represents the discharge from but a portion of the drainage area. Whether this is the portion lying nearest the outlet or some other part of the drainage area, it would be impossible to tell without a very large amount of information. If the storm included a heavy downpour of ten minutes' duration, followed by a drizzle of indefinite duration, the maximum run-off would probably occur when a section of the drainage area at a distance from the gaging point was contributing at the maximum rate, while portions nearer the gaging point were contributing the run-off corresponding to the lighter rainfall which followed the downpour. It is therefore impossible to say what the true contributing drainage area to the maximum run-off amounted to, or what is the proper rate of precipitation with which that run-off should be compared.

A description of the sewer districts gaged in coöperation with the work of this committee is given in the following pages, together with data relating to location and type of rain gage, method of gaging flow, and such other pertinent data as were to be had.

WILMINGTON, DEL.

Shipley Run District. The area of this district is 174 acres, of which 31 per cent. is paved streets and 34 per cent. is the

area of houses, with roofs connected to the drain, making a total of 65 per cent. of impervious area. The pervious area is 35 per cent. and consists mostly of clayey soil. The longitudinal slope of the drainage area is about 2.6 ft. per hundred, and the transverse slope, about 4.5 ft. per hundred. The drain at the point where the gage is placed is of nearly rectangular section, with a width of 10 ft. and depth of 6.5 ft. The invert is of brick and the side walls of stone. Kutter's formula, with a coefficient $n = .015$, was used in computing the flow. The slope of the drain at this point is .0143. The section of channel and slope change 140 ft. above the gage and the section of channel changes 15 ft. below the gage and the slope changes 250 ft. below the gage. The location and make of rain gage are not given but the rain gage sheet bears the name of Queen & Co., Philadelphia.

NEWTON, MASS.

Hyde Brook Drainage Area. This district is located near the center of a small residential city. It may be classed as a suburban area as no portion of it is completely developed with business blocks. The buildings consist almost wholly of residences surrounded by lawns, gardens and fields. The area is 350 acres, of which 6 per cent. is paved* streets, and 22 per cent. roofs, making a total of 28 per cent. impervious area. The pervious area is 72 per cent. The average longitudinal slope is 4.9 ft. per hundred and the average transverse slope 2.3 ft. per hundred. The drain at the point where the gage is placed is of horseshoe section with a width of 10 ft. and a height of 6.4 ft. This gaging station is rather unsatisfactory owing to the fact that the grade changes 160 ft. above and 128 ft. below the gaging point. Kutter's formula was used to determine the flow with a coefficient $n = .013$. The section of channel changes 160 ft. above and 138 ft. below the gaging point. At the latter point the water flows over a flight of steps with a vertical fall of about 9 ft. The rain gage is of the Fergusson type and is placed within the district about half way between the center and gaging point. Much trouble was experienced in keeping the clocks of the rain and sewer gages together and it was partly for this reason that the present city engineer discontinued the use of gages. The period of concentration was taken as 20 minutes.

PAWTUCKET, R. I.

Newell Avenue District (gaged in Esten Avenue Sewer). The area of this district is 146 acres, of which 25 per cent. is

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* Oiled or tarvia streets.

paved streets and 9 per cent. roofs, making a total impervious area of 34 per cent. The pervious area is 66 per cent. and consists chiefly of sand and gravel covered with about 2 ft. of yellow loam. The average longitudinal slope of the district is 1.2 ft. per hundred and the transverse slope 1.5 ft. per hundred. At the gaging station, the drain is built of concrete and is 56 ins. in diameter. Hazen and Williams' formula, with a coefficient $c = 150$, was used to determine the flow; but float measurements of flow in the sewer were made, as a result of which this coefficient was adopted. The gage was placed at a change of grade, the slope being 0.6 ft. per hundred below the gage and 0.9 ft. per hundred above the gage. Mr. Carpenter used the figure of 0.6 ft. per hundred in figuring his flow, after careful measurements of the flow in the sewer, which indicated that to be correct, as closely as the measurements could be taken. The section of channel changes 2 250 ft. above the gage, but there is no change to the outlet, which is 545 ft. below the gage. The rain gage is a Draper Self-Recording Pluviometer of the old type. This gage was changed by Mr. Carpenter so that the chart covered in a space of twenty-four hours what had been originally made to cover seven days. The time of flow through the sewers, as computed by Mr. Carpenter, was $23\frac{3}{4}$ minutes.

LOUISVILLE, KY.

Western Outfall. This is a fully developed city district, the area of which is 2 500 acres. Twenty-two per cent. of the area is paved streets and 14 per cent. roofs, making a total of 36 per cent. impervious area. The total pervious area is 64 per cent., a large part of which is of clay. Mr. Breed has written in regard to this matter, — "The area of paved streets is based upon approximate calculation, and area of roofs is estimated from a count of the house numbers found in the city directory within the limits of the basin. I believe the impervious area is as nearly correct as can be fixed without a thorough survey." The average longitudinal slope of the district is 0.24 ft. per hundred, and the transverse slope, 0.43 ft. per hundred. The grade changes 3 160 ft. above the gage and 4 910 ft. below the gage. The section of channel changes 4 170 ft. above the gage and 4 910 ft. below the gage. It is not clear to just what gage these figures refer, because three gages were used in determining the depth of flow. These three gages gave the following heights, 9.01 ft., 8.64 ft. and 8.97 ft. In regard to this, Mr. Breed says, — "The reading at the intermediate gage, because of its lack of agreement with the others, was thrown out and the depth assumed was 9.0 ft." At the gaging station the sewer was

originally 10 ft. 6 in. in height, but now measures 10.38 ft., probably due to settlement of the crown. The slope of the sewer, as obtained by actual elevations, is .058 per cent. and Kutter's formula, with a coefficient n = .015, was used to determine the quantity. The sewer is built of brick laid in cement mortar and is now about forty years old. The rain gage is of the Friez type and is placed about 1 000 ft. beyond the boundary of the district and about $1\frac{3}{4}$ miles from the center of the district. The period of concentration has been taken as 80 minutes.

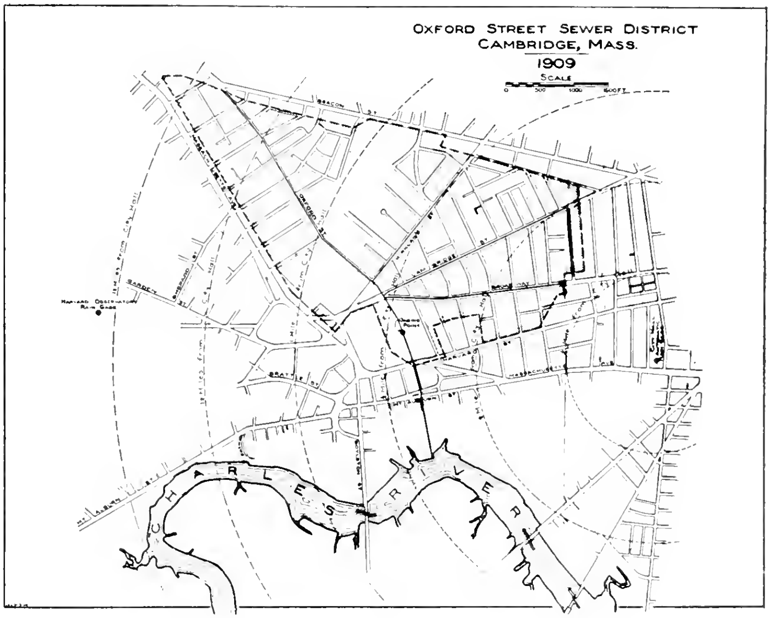

FIG. 35.

CAMBRIDGE, MASS.

Oxford Street District (Fig. 35). The area of this district is 400 acres, of which 16 per cent. is pavements and 13 per cent. roof area, making a total of 29 per cent. impervious area. The pervious area is 71 per cent., about one tenth of which is clayey soil. The slope of the drainage area is generally flat. The gaging station of the sewer is of brick and is 4 ft. 6 in. x 4 ft. (Fig. 36). Kutter's formula, with a coefficient n = .015, was used to determine the discharge. The slope at this point is 0.1

ft. per hundred. The rate of grade changes 800 ft. above the point of observation and 570 ft. below the point of observation. The size of the channel changes 800 ft. above the point of observation and there is no change below. The rain gage, which is of the Fergusson type, is placed at City Hall, about three fourths of a mile from the gaging station and about one mile from the center of the district. The period of concentration was computed as forty minutes.

Data Relative to the Oxford Street Drainage Area Located in Cambridge, Mass., as Noted, 1909.

SECTION OF DRAIN.

Brick, $n = 0.015$.

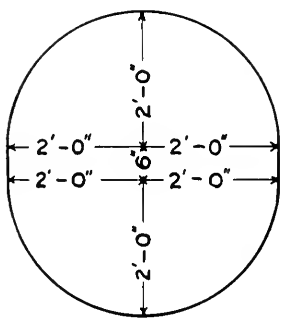

Fig. 36.

Rate of grade in ft. per 100 at point of observation 0.10
Rate of grade changes to 0.08 ft. per 100 800 ft. above point of observation.
Rate of grade changes to 0.25 ft. per 100 570 ft. below point of observation.
Size of channel changes to 3 ft. x 3 ft. 4 in. 800 ft. above point of observation.
Area contributing to flow, 400 acres.

IMPERVIOUS AREA.

		Per Cent.
Area of paved streets, including macadam	64 acres	16
Area of houses with roofs connected, or discharging on an impervious area	52 acres	13
Total	116 acres	29

PERVIOUS AREA.

		Per Cent.
Area of developed land	284 acres	71
Total	284 acres	71
Total area as above	400 acres	

Method of computing discharge, Kutter's formula, $n = 0.015$.

Slope of water surface at point of observation, 0.10 ft. per 100.

Remarks. — Mostly sand and gravel covered with soil, about 10 per cent. of area clay soil.

Shepard Street District. This district can best be described by the following tabulation:

Area	56.5 acres
Percentage roof area	12
Percentage street area	24
Percentage lawns and gardens	64
No. of houses	155
Houses from which roof water runs directly to sewer	80
General slope of area	.028
General character of soil	Sandy

At the gaging station the drain is of egg-shaped section, built of brick, $28\frac{3}{4}$ ins. x $37\frac{1}{4}$ ins. Kutter's formula, $n = .013$, was used to figure the discharge. No figures were given as to the period of concentration, but it was assumed by Greeley to be twenty minutes. The rain was measured by an ordinary gage outside of the area and by an automatic gage about one mile distant.

Sherman Street District. The characteristics of this area are shown in the following tabulation:

Area	68 acres
Percentage roof area	10
Percentage street area	18
Percentage lawns and gardens	72
No. of houses	292
Houses from which roof water runs directly to sewer	87
General slope of area	.032
General character of soil	Clay

At the gaging station the drain is of brick and nearly circular in section, being 36 ins. x 40 ins. Kutter's formula, $n = .013$, was used to determine the discharge. The rain was measured by an ordinary gage outside the area and an automatic gage about one mile distant. The period of concentration, as estimated by Greeley, is twenty minutes.

Bath Street Area. The area of this district is 223 acres. The slopes are rather flat and the soil sandy. At the gaging station the sewer is of oval shape, with a height and width of

4 ft. 4½ ins. and 3 ft. 4½ ins., respectively. The slope of the sewer is 0.35 per cent. The flow was measured over a weir 4 ft. wide with two end contractions. The rain gage was about one mile distant. There are no figures for use in figuring the period of concentration.

PHILADELPHIA, PA.

Seventh Survey District. The area of this district is 1 360 acres, of which two thirds is improved property and one third unimproved. At the gaging station the sewer is 13 ft. in diameter and built of brick. It has a slope of 0.294 per cent. From gagings that have been made from time to time with a velocity meter, the value of *n* in Kutter's formula was found to be .017. The rain gage was located just outside of the district and about one mile from the center of the district.

Table 2.* — Measurement of Storm Water Flow in Sewers.

Washington, D. C.

As reported by Capt. R. L. Hoxie in Trans. Am. Soc. C. E., Vol. 25, pp 81–82.

New York Avenue Sewer, draining 436 acres, of which 200 acres are closely built, and streets paved with asphalt; 156 acres sparsely built, but with streets mostly paved with asphalt; 80 acres open park. (Probably 55 to 60 per cent. impervious.) Time of concentration, about 25 minutes.

Date.	Max. Rate of Precipation. Ins. per Hr.	Duration. Min.	Max. Rate of Run-off. c.f.s. per Acre.	Coefficient.
June 28, 1881	4.23	25	2+	0.48+

New York Avenue Sewer: Area above gaging point, 200 acres; nearly 100 per cent. impervious.

1884	2.00	15	1.50+	0.75
June 28, 1885	0.90	37	0.90	1.00

* From Metcalf and Eddy's "American Sewerage Practice."

TABLE 3.* — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

ROCHESTER, N. Y. Gagings of Emil Kuichling, data from Trans. Am. Soc. C. E., Vol. 20, 1889, p. 1. Gagings made by maximum flow gages, determining slope from records of pairs of gages. Rain carefully measured but not by automatic gages.

District I. Area, 356.9 acres, residential; about half has population of 35 per acre; remainder sparsely settled, agricultural. Soil mostly clayey loam. Earth roads. Maximum time of flow in sewers estimated at 34 minutes. Time of concentration, 44 minutes. Impervious area, 15 per cent.

Date.	Max. Intensity of Rainfall, Ins. per Hr.	Corresponding Precipitation on Drainage Area, c.f.s.	Max. Sewer Discharge, c.f.s.	Coefficient = Ratio of Discharge to Precipitation.	Remarks.
December 10, 1887	0.31	110.6	15.3	0.14	Preceded and followed by lighter rains.
April 5, 1888	0.24	85.7	8.94	0.10	Ditto.
May 4,	0.30	107.1	7.32	0.07	Ditto.
May 9,	1.32	469.5	77.0	0.16	Sudden shower, followed by light rain.
May 12,	0.30	107.1	11.8	0.11	Preceded and followed by lighter rain.
May 26,	1.00	356.9	30.8	0.09	Ditto.
June 2,	0.40	142.8	7.81	0.06	Sudden shower.
June 24,	1.55	553.2	40.7	0.07	Ditto.
June 24,	2.62	935.1	58.8	0.06	Ditto.
June 28,	0.80	285.5	40.7	0.14	Preceded and followed by heavy rain.
July 11,	0.76	271.2	19.9	0.07	Heavy shower preceded by lighter rain.
July 18,	0.75	267.7	20.5	0.08	Preceded and followed by lighter rain.
August 4,	1.00	356.9	16.5	0.05	Sudden shower.
August 16,	1.62	576.8	27.2	0.05	Ditto.
August 17,	1.33	475.9	25.8	0.06	Ditto.
August 26,	2.50	892.4	35.3	0.04	Intensity estimated roughly.
September 16,	0.47	167.7	33.3	0.20	Sudden shower.

* Copied from Metcalf and Eddy's "American Sewerage Practice."

TABLE 4.* — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

ROCHESTER, N. Y., *continued.*

District XVII. Well-developed area of 92.3 acres. Population, 35 per acre. One fifth of streets paved with asphalt, one fourth with stone block, remainder macadam and gravel. Buildings mostly single residences; some business blocks and apartments. Soil, clayey loam. Half of the area is nearly level. Maximum time of flow in sewers, 16 minutes; time of concentration, 24 minutes. Impervious area, about 30 per cent.

Date.	Max. Intensity of Rainfall. Ins. per Hr.	Corresponding Precipitation on Drainage Area, c.f.s.	Max. Sewer Discharge. c.f.s.	Coefficient = Ratio of Discharge to Precipitation.	Remarks.
December 10, 1887	0.31	28.6	7.43	0.26	Preceded and followed by lighter rain.
April 5, 1888	0.24	22.2	4.61	0.21	Ditto.
May 4, ...	0.30	27.7	7.82	0.28	Ditto.
May 9, ...	0.75 (?)	69.2	18.0	0.26	Intensity estimated.
May 12, ...	0.30	27.7	4.70	0.17	Preceded and followed by lighter rain.
May 26, ...	1.00	99.3	10.8	0.12	Ditto.
June 2, ...	0.40	36.9	3.23	0.09	Sudden shower.
June 24, ...	2.62	242.	28.5	0.12	Sewer surcharged.
June 28, ...	0.80	73.8	27.7	0.37	Preceded and followed by lighter rain.
July 11, ...	0.76	70.1	13.6	0.20	Heavy shower preceded by lighter rain.
July 18, ...	0.75	69.2	7.14	0.10	Preceded and followed by lighter rain.
August 4, ...	1.00	92.3	12.7	0.14	Sudden shower.
August 16, ...	1.62	149.	28.5	0.19	Sewer surcharged.
August 17, ...	1.33	123.	10.9	0.09	Sudden shower.
August 26, ...	2.50	231.	28.5	0.12	Sewer surcharged.
September 16, ...	0.47	43.4	16.1	0.37	Sudden shower.

* From Metcalf and Eddy's "American Sewerage Practice."

TABLE 5.* — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

ROCHESTER, N. Y., *continued.*

District IX. Well-developed residential district of 133 acres; population, 36 per acre. Dwellings mostly large and rather close together. Streets mostly macadam or gravel. Soil generally loamy. Maximum time of flow in sewer, 15 minutes. Time of concentration, 23 minutes. Impervious area, about 38 per cent.

Date.	Max. Intensity of Rainfall. Ins. per Hr.	Corresponding Precipitation on Drainage Area, c.f.s.	Max. Sewer Discharge, c.f.s.	Coefficient = Ratio of Discharge to Precipitation.	Remarks.
December 10, 1887	0.31	41.2	17.1	0.42	Preceded and followed by lighter rain.
April 5, 1888	0.24	31.9	12.2	0.38	Ditto.
May 4,	0.30	39.9	14.4	0.36	Ditto.
May 9,	0.75 (?)	99.8	29.0	0.29	Intensity estimated.
May 12,	0.30	39.9	11.8	0.30	Preceded and followed by lighter rain.
May 26,	1.00	133.	24.9	0.19	Ditto.
June 2,	0.40	53.2	20.0	0.38	Sudden shower.
June 24,	2.62	348.	46.0	0.13	Sewer surcharged.
June 28,	0.80	106.	37.5	0.35	Preceded and followed by lighter rain.
July 11,	0.76	101.	22.1	0.22	Heavy shower preceded by lighter rain.
July 18,	0.75	99.8	14.8	0.15	Preceded and followed by lighter rain.
August 4,	1.00	133.	19.9	0.15	Sudden shower.
August 16,	1.62	215.	38.2	0.18	Ditto.
August 17,	1.33	177.	21.1	0.12	Ditto.
August 26,	2.50	333.	46.0	0.14	Sewer surcharged.

* From Metcalf and Eddy's "American Sewerage Practice."

TABLE 6.* — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

ROCHESTER, N. Y., *continued.*

District IV. Well-developed area of 128.7 acres; about 4 800 ft. long and 1 200 ft. wide. Average density of population, 32 per acre. Many business blocks in one portion, remainder residential. Soil mostly clayey loam. About one third of streets paved, mostly with macadam, but some stone block and asphalt. Time of flow in sewer, 18 minutes. Time of concentration, 26 minutes. Impervious area, about 30 per cent.

Date.	Max. Intensity of Rainfall. Ins. per Hr.	Corresponding Precipitation on Drainage Area, c.f.s.	Max. Sewer Discharge, c.f.s.	Coefficient = Ratio of Discharge to Precipitation.	Remarks.
December 10, 1887	0.31	39.8	9.27	0.24	Preceded and followed by lighter rain.
April 5, 1888	0.24	30.9	4.80	0.16	Ditto.
May 4,	0.30	38.6	5.56	0.14	Ditto.
May 9,	1.00	128.7	33.7	0.26	Intensity estimated.
May 12,	0.30	38.6	6.09	0.16	Preceded and followed by lighter rain.
May 26,	1.00	128.7	33.3	0.26	Ditto.
June 2,	0.40	51.5	4.67	0.09	Sudden shower.
June 24,	2.62	337.2	71.3	0.21	Ditto.
June 28,	0.80	103.0	29.5	0.29	Preceded and followed by lighter rain.
July 11,	0.76	97.8	15.4	0.16	Heavy shower preceded by lighter rain.
July 18,	0.75	96.5	11.8	0.12	Preceded and followed by lighter rain.
August 4,	1.00	128.7	12.8	0.10	Sudden shower.
August 16,	1.62	208.0	25.9	0.13	Ditto.
August 17,	1.33	171.6	14.9	0.09	Ditto.
August 26,	2.50	321.8	39.3	0.12	Ditto.
September 16,	0.47	60.5	23.1	0.38	Ditto.

* From Metcalf and Eddy's "American Sewerage Practice."

TABLE 7.* — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

ROCHESTER, N. Y., *continued*.

District X. Well-developed area of 25.1 acres, with population of 40 per acre. Long narrow strip containing many business blocks and apartment houses, as well as single residences. Streets mostly macadamized. Soil, clayey loam. Maximum time of flow in sewers, 10 minutes. Time of concentration, 16 minutes. Impervious area, about 50 per cent.

Date.	Max. Intensity of Rainfall. Ins. per Hr.	Corresponding Precipitation on Drainage Area, c.f.s.	Max. Sewer Discharge, c.f.s.	Coefficient = Ratio of Discharge to Precipitation.	Remarks.
December 10, 1887	0.31	7.80	4.54	0.58	Preceded and followed by lighter rain.
May 4, 1888	0.30	7.54	4.89	0.65	Ditto.
May 9,	0.75 (?)	18.8	9.81	0.52	Intensity estimated.
May 12,	0.30	7.54	2.66	0.35	Preceded and followed by lighter rain.
May 26,	1.00	25.1	7.94	0.32	Ditto.
June 24,	2.62	65.8	21.0	0.32	Sewer surcharged. Flow estimated at maximum capacity before surcharging.
June 28,	0.80	20.1	7.09	0.35	Preceded and followed by lighter rain.
July 11,	0.76	19.1	8.01	0.41	Heavy shower preceded by lighter rain.
July 18,	0.75	18.8	4.70	0.25	Preceded and followed by lighter rain.
August 16,	1.62	40.6	10.0	0.25	Sudden shower.
August 17,	1.33	33.5	6.17	0.18	Ditto.
August 26,	2.50	62.8	21.0	0.34	Sewer surcharged.

* From Metcalf and Eddy's "American Sewerage Practice."

TABLE 8.* — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

NEW YORK CITY. Sixth Avenue Sewer, gaged by Rudolph Hering in 1887–88 by recording float gage. A well-built-up and paved section in the lower part of the city, area 221 acres, regular surface slope of about 0.007. About 90 per cent. of area impervious, remainder grass. Population, 170 per acre. Time of concentration, 15 minutes†; nearest recording rain gage, 2 miles distant.

Data quoted from C. E. Gregory, Trans. Am. Soc. C. E., Vol. 58, 1907, p. 464.

Date.	Max. Av. Rate of Rainfall for Period = Time of Concentration. Ins. per Hr.	Corresponding Max. Rate of Run-off Observed, c.f.s. per Acre.	Coefficient = Ratio of Run-off to Precipitation.	Remarks.
December 28, 1887	0.730	0.290	0.39	
December 28,	0.25	0.18	0.72	
February 25, 1888	0.49	0.28	0.57	
February 25,	0.36	0.27	0.75	
June 26,	2.367	1.022	0.43	
July 19	1.850	0.666	0.36	
August 4	2.910	1.162	0.40	Near end of storm.
August 21,	2.180	0.880	0.40	At beginning of storm.
August 21,	1.347	0.470	0.34	Near end of storm.
August 21,	1.20	0.65	0.54	
August 21,	1.07	0.90	0.84	

* From Metcalf and Eddy's "American Sewerage Practice."

† Not including time required for water to reach inlets.

TABLE 9.* — MEASUREMENT OF STORM-WATER FLOW IN SEWERS.

MILWAUKEE, WIS. Experiments of Logermann and Nommenson, reported in *Engineering News*, June 6, 1901. Gagings in 8-ft. sewer having slope of 0.0025. Rain determined by Weather Bureau automatic gage and checked by ordinary rain gage: these gages 1 to 2 miles distant from sewer district but records considered applicable to storms reported. Total area of sewer district, 1 138 acres, of which 18.5 per cent. is occupied by streets. Fair average residential district, well built up. Several streets have block pavements or macadam, but most of them have gravel surface. Time of concentration for whole area with maximum velocity in sewer, 44 minutes, as computed for storms gaged, with velocities actually obtained, time of concentration ranged from 67 to 100 minutes. It was assumed that the proportion of the drainage area contributing to maximum flow was the same as the ratio between duration of rain at maximum rate and computed time of concentration under existing conditions. In only one storm was entire area tributary at time of maximum flow.

Date, 1898.	Max. Av. Rate of Rainfall Observed. Ins. per Hr.	Duration of This Rainfall. Min.	Time Required for Concentration with Velocity Actually Obtained. Min.	Corresponding Percentage of Total Area Contributing to Max. Flow.	Precipitation on Tributary Area, c.f.s.	Max. Rate of Run-off, as Gaged.	Coefficient = Ratio of Run-off to Precipitation.
July 31	0.10	30	89	33.7	38.3	6.42	0.17
August 2	0.28	85	75	100.0	318.	65.1	0.20
August 6	0.17	15	100	15.0	29.4	5.72	0.19
August 23	0.72	25	67	37.4	303.	117.	0.38

(Recomputed from published figures, which contain error.)

* From Metcalf and Eddy's "American Sewerage Practice."

TABLE 10.* — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

HARTFORD, CONN. Franklin Avenue Sewer, gaged at South St. by recording float gage. Sewer, 6 ft. diam., slope 0.002. Hydraulic grade assumed parallel to invert. Area drained, 477 acres; residential, about one half fairly thickly built up, remainder somewhat sparse. Density of population, 12 per acre. Time of concentration estimated to exceed 25 minutes.

Results of computations by Metcalf & Eddy from data in paper by F. L. Ford in Trans. Conn. Soc. C. E., 1900–01, p. 133; rain record is that of city hall gage, one-half mile from center of sewer district. (Computations for storage in sewer apply only to trunk sewer; no allowance for storage in branch sewers.)

Date, 1900.	Condition of Ground.	Max. Av. Rate of Rainfall for Period = Time of Concentration. Ins. per Hr.	Duration of Precipitation at This Rate. Min.	Corresponding Discharge at 100 per cent. Run-off, c.f.s.	Observed Time from Beginning of Max. Rain to Max. Flow. Min.	Rate of Max. Flow in Sewer in Excess of Ord. Flow, c.f.s.	Add for Storage in Sewer, c.f.s.	Total Storm Water Run-off, c.f.s.	Coefficient = Ratio of Run-off to Precipitation.
July 25...	Dry.	0.75	40	360	40	40	24	64	0.18
July 25...	Wet by previous rain.	1.00	60	477	60	78	10	88	0.18
October 8...	Ditto.	0.50	85	238	65	22	4	26	0.11

* From Metcalf and Eddy's "American Sewerage Practice."

TABLE 11.* — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

HARTFORD, CONN. Franklin Avenue Sewer, gaged at Bond Street by recording float gage. Sewer, 4 ft. diam.; slope, 0.003. Hydraulic grade assumed parallel to invert. Area drained, 263.5 acres; residential, densely built up except for institution occupying about 50 acres. Density of population, 15.5 per acre. Time of concentration estimated to exceed 22 minutes.

Results of computations by Metcalf & Eddy from data in report of F. L. Ford to City of Hartford, 1903. Rain record used is that of city hall gage, one-half mile from center of sewer district. Computations for storage in sewer apply only to trunk sewer; no allowance for storage in laterals.

Date.	Condition of Ground.	Max. Av. Rate of Rainfall for Period = Time of Concentration. Ins. per Hr.	Duration of Precipitation at This Rate. Min.	Corresponding Discharge at 100 per cent. Run-off, c.f.s.	Observed Time from Beginning of Max. Rain to Max. Flow. Min.	Rate of Max. Flow in Sewer in Excess of Ord. Flow, c.f.s.	Add for Storage in Sewer, c.f.s.	Total Storm Water Run-off, c.f.s.	Coefficient = Ratio of Run-off to Precipitation.
March 11, 1901	Covered with ice.	0.35	120	167	?	195	23	218	1.30 (?)
July 11, 1901	Dry.	3.75	20	990	20	75	58	133	0.14
Feb. 28, 1902	Wet by previous rain.	1.00	20	263	?	60	12+	72	0.27

* From Metcalf and Eddy's "American Sewerage Practice."

TABLE 12.* — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

BIRMINGHAM, ENGLAND. Measurements of D. E. Lloyd-Davies, reported in Proc. I. C. E., Vol. 164, p. 5. Rainfall from Edgbarton Observatory in Birmingham. Run-off computed from two automatic sewer gages for each sewer gaged.

Moseley Street Sewer. Area drained, 312.5 acres. Population, 125 per acre. Area wholly impervious, 22 per cent. in street pavements, 78 per cent. roofs. Average slope of surface, 1 in 60. Minimum time of concentration, 18 minutes.

Date, 1904.	Max. Intensity of Rainfall during Time of Concentration. Ins. per Hr.	Max. Resulting Rate of Run-off, c.f.s. per Acre.	Coefficient = Ratio of Run-off to Rainfall.
January 10	0.330	0.304	0.92
January 14	0.274	0.283	1.03
January 26	0.122	0.101	0.83
January 27	0.210	0.147	0.70
January 30	0.280	0.262	0.94
February 4	0.198	0.246	1.24
February 8	0.297	0.329	1.11
February 13	0.280	0.252	0.90
March 8	0.100	0.088	0.88
March 29	0.132	0.160	1.23
April 14	0.165	0.124	0.75
April 16	0.132	0.139	1.05
May 2	0.297	0.289	0.97
May 21	0.198	0.178	0.90
May 27	0.726	0.795	1.09
July 26	0.866	0.836	0.96
August 5	0.462	0.193	0.42
September 3	0.066	0.043	0.65
September 12	0.326	0.110	0.34
October 1	0.099	0.074	0.75
November 7	0.099	0.065	0.66
November 10	0.139	0.105	0.76
November 21	0.229	0.127	0.55
December 4	0.109	0.065	0.60
December 5	0.264	0.091	0.34
December 10	0.075	0.073	0.97
December 12	0.145	0.110	0.76
December 14	0.065	0.058	0.89

* From Metcalf and Eddy's "American Sewerage Practice."

TABLE 13.* — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

BIRMINGHAM, ENGLAND, *continued.*

Charlotte Road Sewer. Area drained, 232 acres. Impervious area, 18 per cent., of which pavements constitute 10 per cent. Population, 17 per acre. Minimum time of concentration, 12 minutes.

Date, 1904.	Max. Intensity of Rainfall during Time of Concentration. Ins. per Hr.	Max. Resulting Rate of Run-off, c.f.s. per Acre.	Coefficient = Ratio of Run-off to Rainfall.
January 14	0.274	0.054	0.20
January 26	0.122	0.025	0.20
January 27	0.210	0.040	0.19
January 30	0.280	0.074	0.26
February 4	0.198	0.039	0.20
February 8	0.297	0.081	0.27
February 13	0.280	0.049	0.18
March 8	0.100	0.029	0.29
March 29	0.132	0.030	0.23
April 14	0.165	0.032	0.20
April 16	0.183	0.040	0.22
May 2	0.297	0.072	0.24
May 21	0.198	0.030	0.15
May 27	0.68	0.181	0.27
July 26	1.04	0.273	0.26
August 5	0.675	0.128	0.19
August 17	0.338	0.051	0.15
August 22	0.165	0.048	0.29
September 3	0.100	0.025	0.25
September 12	0.420	0.098	0.23
October 1	0.175	0.049	0.28

TABLE 14.* — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

BIRMINGHAM, ENGLAND, *continued.*

Bordesley Street Sewer. Area drained, 19.32 acres; 100 per cent. impervious surface. Population, 146 per acre. Minimum time of concentration, 6.5 minutes.

Date, 1904.	Max. Intensity of Rainfall during Time of Concentration. Ins. per Hr.	Max. Resulting Rate of Run-off, c.f.s. per Acre.	Coefficient = Ratio of Run-off to Rainfall.
January 27	0.360	0.346	0.96
January 30	0.350	0.346	0.99
February 13	0.354	0.346	0.98
March 8	0.240	0.258	1.07
March 29	0.240	0.304	1.26
April 14	0.414	0.386	0.93
April 16	0.368	0.386	1.05
May 1	0.644	0.760	1.18

* From Metcalf and Eddy's "American Sewerage Practice."

TABLE 15.* — GAGINGS OF STORM-WATER FLOW IN SEWERS.

CAMBRIDGE, MASS. (As reported by John R. Freeman — Report on Charles River Dam — and interpreted by Samuel A. Greeley in Jour. W. S. E., September, 1913.)

	Shepard St.	Sherman St.
Tributary area, acres	56.5	68
Percentage roof area	12	10
Percentage street area	24	18
Percentage lawns and gardens	64	72
Number of houses	155	292
Houses from which roof water runs directly to sewer,	80	87
General slope of area	.028	.032
General character of soil	Sandy	Clay

Time of concentration not given; assumed by Greeley as 20 minutes in both cases. Rain measured by ordinary gage between drainage areas, and by automatic gage about one mile distant.

A. Gagings during long steady rains.

	Date, 1900.	Time after Beginning of Rain. Hrs.—Min.	Av. Rate of Rainfall for 20 Min. Ins. per Hr.	Max. Rate of Discharge in Sewer, c.f.s. per Acre.	Coefficient.
Shepard St. Sewer...	Feb. 25	2 — 10	0.30	0.07	0.23
		3 — 55	0.34	0.13	0.38
		5 — 30	0.275	0.15	0.55
		6 — 20	0.27	0.16	0.59
	May 3	5 — 25	0.43	0.05	0.14
		6 — 25	0.56	0.14	0.25
		8 — 25	0.30	0.095	0.32
Sherman St. Sewer ..	May 3	5 — 35	0.43	0.028	0.65
		6 — 55	0.565	0.44	0.78
		8 — 35	0.33	0.33	1.00

B. Gagings of run-off from heavy summer showers.

Shepard St..........	July 25		1.00	0.32	0.32
	Aug. 10		0.70	0.35	0.50
	Aug. 27		1.80	0.51	0.28
Sherman St..........	July 25		1.00	0.45	0.45
	Aug. 10		0.70	0.20	0.29
	Aug. 27		1.80	0.70	0.39

C. Gagings of run-off from steady heavy rains, on ground previously saturated.

Shepard St..........			0.365	0.17	0.47
			0.15	0.08	0.53
Sherman St..........			0.365	0.365	1.00

* From Metcalf and Eddy's "American Sewerage Practice."

TABLE 16.

CAMBRIDGE, MASS.

*Shepard Street Sewer.** See preceding table for description of district.

Date, 1900.	Max. Rate of Rainfall. Ins. per Hr.	Duration of This Rate.	Max. Rate of Run-off, c.f.s. per Acre.	Coefficient.
		Hr. Min.		
February 12.....	0.28	1 — 10	0.19	0.68†
February 22.....	0.36	0 — 30	0.31	0.86†
February 25.....	0.30	0 — 30	0.07	0.23†
February 25.....	0.34	0 — 30	0.135	0.40
February 25.....	0.27	0 — 35	0.15	0.56
February 25.....	0.26	1 — 00	0.16	0.62
February 25.....	0.20	0 — 40	0.09	0.45
May 3.....	0.56	1 — 0	0.13	0.23
May 3.....	0.30	0 — 50	0.10	0.33
September 17.....	0.36	3 — 40	0.17	0.47
September 18.....	0.90	0 — 30	0.135	0.15
September 18.....	0.60	0 — 30	0.18	0.30
September 21.....	0.62	0 — 25	0.22	0.35
November 9.....	0.52	0 — 20	0.17	0.33
November 25.....	0.15	0 — 30	0.08	0.53

* Data from Lewis M. Hastings, City Engineer, to Run-off Committee of Boston Society of Civil Engineers.

† Ground frozen; no snow.

TABLE 17.

CAMBRIDGE, MASS.

*Bath Street Sewer.** Area, 223 acres. Flow measured over weir. No data on impervious surface or character of soil. Rains of less duration than 30 minutes are omitted. Sandy soil. Flat slopes. Rain gage about 1 mile distant.

Date.	Max. Rate of Rainfall. Ins. per Hr.	Duration of This Rate.	Max. Rate of Run-off, c.f.s. per Acre.	Coefficient.
		Hr. Min.		
Nov. 29, 1910.....	0.20	1 — 0	0.032	0.16
Feb. 4, 1911.....	0.52	0 — 30	0.067	0.13
June 6, ...	0.23	1 — 0	0.045	0.20
Nov. 12, ...	0.35	1 — 0	0.05	0.14

* From data reported by Lewis M. Hastings, City Engineer, to Run-off Committee of Boston Society of Civil Engineers.

TABLE 18.

CAMBRIDGE, MASS. *Oxford Street Sewer.** Drainage area, 400 acres, of which 16 per cent. is made up of pavements and 13 per cent. of roofs; total impervious area, 29 per cent. Soil mostly gravelly, but about 10 per cent. of district is clayey. Slopes generally flat. Rain gage at city hall about three-fourths mile from gaging station and about 1 mile from center of district. Time of concentration computed as 40 minutes.

Date.	Max. Rate of Rainfall. Ins. per Hr.	Duration of This Rate. Hr. — Min.	Max. Rate of Run-off, c.f.s. per Acre.	Coefficient.	
April 23, 1909	0.13	1 — 0	0.016	0.12	Beginning of storm.
April 23, 1909	0.18	0 — 50	0.037	0.21	2 hr. after beginning of rain.
June 13–14, 1909	0.58	1 — 0	0.08	0.14	Beginning of storm.
June 13–14,	0.31	0 — 35	0.059	0.19	$1\frac{1}{4}$ hr. after beginning of rain.
July 3,	0.17	0 — 50	0.024	0.14	$4\frac{1}{2}$ hr. after beginning of rain.
September 1,	0.48	0 — 35	0.041	0.09	Beginning of storm.
September 1,	0.14	0 — 40	0.03	0.21	$1\frac{1}{4}$ hr. after beginning of rain.
September 27,	0.25	1 — 15	0.044	0.18	Beginning of storm.
September 28,	0.08	1 — 0	0.015	0.19	$\frac{1}{2}$ hr. after beginning of rain.
September 28,	0.14	0 — 35	0.022	0.16	5 hr. after beginning of rain.
September 28,	0.15	1 — 20	0.031	0.21	10 hr. after beginning of rain.
September 28,	0.12	0 — 40	0.023	0.19	$13\frac{1}{2}$ hr. after beginning of rain.

* From data reported by Lewis M. Hastings, City Engineer, to Run-off Committee of Boston Society of Civil Engineers.

TABLE 19.

PAWTUCKET, R. I.

*Newell Avenue Sewer District.** Drainage area, 146 acres, of which 25 per cent. consists of pavements and 9 per cent. of roofs; total impervious area, 34 per cent. Soil, sand and gravel covered with 2 ft. of loam. Average surface slope less than 2 per cent. Rain gage about 1 mile distant. Slope of sewer changes at gaging point; no change in section for 2 250 ft. above gage; outlet is 545 ft. below. Flow computed by Hazen-Williams formula with $c = 150$, using slope of sewer downstream from gage. Time of flow in sewer from most distant point computed as $23\frac{3}{4}$ minutes.

Date.	Max. Rate of Rainfall. Ins. per Hr.	Duration of this Rate.	Max. Rate of Run-off, c.f.s. per Acre.	Coefficient.	Time after Beginning of Storm.
		Hr. Min.			
Spring Months.					
Mar. 25, 1909.....	0.26	0 — 48	0.092	0.35	
Summer Months.					
Aug. 26, 1908.....	0.50	0 — 30	0.16	0.32	
June 17, 1910.....	0.22	0 — 50	0.071	0.33	
Aug. 15, 1910.....	0.19	0 — 45	0.058	0.31	
Aug. 28, 1910.....	0.24	0 — 35	0.064	0.27	
Fall Months.					
Oct. 20, 1906.....	1.02	0 — 35	0.302	0.30	
Sept. 4–5, 1907....	0.69	0 — 25	0.299	0.43	
Sept. 28–29, 1907 .	0.29	0 — 50	0.128	0.44	
Oct. 8, 1907.....	0.46	0 — 50	0.189	0.43	2 hr., 40 m.
Nov. 4, 1910.....	0.23	1 — 07	0.112	0.49	
Nov. 29, 1910.....	0.17	1 — 40	0.044	0.26	4 hr., 20 m.
Winter Months.					
Dec. 23, 1907.....	0.51	0 — 37	0.295	0.58	
Feb. 19, 1908.....	0.70	0 — 54	0.462	0.66	3 hr., 15 m.
Feb. 26, 1908.....	0.15	1 — 28	0.075	0.50	
Feb. 26, 1908.....	0.22	1 — 0	0.192	0.87	
Dec. 7, 1908.....	0.30	2 — 10	0.148	0.49	6 hr.
Feb. 10, 1909.....	0.30	0 — 30	0.148	0.49	

* From figures reported by George A. Carpenter, City Engineer, to Run-off Committee of Boston Society of Civil Engineers, eliminating all storms of duration less than twenty-five minutes.

TABLE 20.

NEWTON, MASS.

Hyde Brook drainage area,* 350 acres, of which about 28 per cent. is impervious. Suburban residence district well developed. Small brook enclosed in covered masonry channel. Rain gage within district, about halfway between center and gaging point. Computations by Kutter's formula, using $n=0.013$. Gaging point not very satisfactory, since grade changed 160 ft. above and 138 ft. below gaging point. Section of channel changed 193 ft. above and 292 ft. below gaging station; at this latter point the water falls over a flight of steps with a vertical fall of about 9 ft. Time of concentration, 20 minutes.

Date.	Max. Av. Rate of Rainfall for 20 Min. Ins. per Hour.	Max. Rate of Run-off, c.f.s. per Acre.	Coefficient.	
Sept. 4, 1907.......	1.40	0.61	0.43	After $1\frac{1}{4}$ hr. of rain.
Aug. 7, 1908.......	2.55	0.71	0.28	Beginning of storm.

* Data from Edwin H. Rogers, City Engineer, to Run-off Committee of Boston Society of Civil Engineers. Gagings begun by the late Irving T. Farnham, Mr. Rogers' predecessor.

TABLE 21.

LOUISVILLE, KY.

*Western Outfall Sewer.** Draining 2 500 acres. Sewer 10.38 ft. diameter, slope 0.058 (from levels). Depth of flow observed at three points a short distance apart; considerable difference was noted; the average was used, 9.0 ft., and the discharge computed by Kutter's formula, using $n=0.015$. Rain gage about 1 000 ft. beyond boundary of district, and about $1\frac{3}{4}$ miles from center of district. A fully developed city district, about 36 per cent. impervious. Average surface slope about 0.004. Soil, clayey. Computed time of flow in sewer from most distant point, 73 minutes; time of concen tration assumed as 80 minutes.

Date.	Max. Av. Intensity of Rainfall for 80 Min. Ins. per Hr.	Max. Rate of Run-off, c.f.s. per Acre.	Coefficient.
June 9–10, 1910.....	0.60	0.193	0.32

* Data from J. B. F. Breed, Chief Engineer, Commissioners of Sewerage, to Run-off Committee, Boston Society of Civil Engineers.

TABLE 22.

WILMINGTON, DEL.

*Shipley Run Drainage Area.** 174 acres, with 31 per cent. paved surfaces and 34 per cent. roofs. Total impervious area, 65 per cent. Soil, clayey; general surface slope about 4 per cent. Flow computed by Kutter's formula, using $n=0.015$. Gaging point not very satisfactory, as grade and section both changed 140 ft. above and 15 ft. below point where depth was gaged. Time of concentration not given; assumed not to exceed 20 minutes.

Date.	Max. Rainfall Rate for 20 Min. Ins. per Hr.	Max. Rate of Run-off, c.f.s. per Acre.	Coefficient.
July 25, 1908.......	3.90	3.1	0.79

NOTE. Rain had been falling heavily, but at a somewhat lesser rate, for 35 minutes before the beginning of the downpour, which caused the maximum run-off.

* Data from A. J. Taylor, Engineer of Sewers, to Run-off Committee of Boston Society of Civil Engineers.

TABLE 23. — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

PHILADELPHIA, PA. Gaging point in 13 ft. sewer at Twelfth and Diamond streets. Area drained, 1 360 acres, two thirds of which is improved property. Time of flow in sewer at maximum velocity, about 33 minutes. Time of concentration assumed as 40 minutes.

Data published in annual reports of Bureau of Surveys, supplemented by information submitted to Run-off Committee of Boston Society of Civil Engineers by George S. Webster, Chief Engineer, Bureau of Surveys. Intensity of rainfall for periods from 10 to 60 minutes' duration are given, and the ratio between run-off and the 30-, 50- and 60-minute precipitation rates are given for comparison.

Date.	Intensity of Rainfall for 40 Min. Ins. per Hr.	Max. Rate of Flow in Sewer, c.f.s. per Acre.	Coefficient.	Ratio between Max. Rate of Flow and Rainfall. Rate for —		
				30 Min.	50 Min.	60 Min.
1903.						
June 10....	1.64*	0.49	0.30	—	—	—
June 10....	1.45	1.33	0.92	—	—	—
1906.						
May 28....	1.39	1.02	0.73	0.62	0.90	1.04
June 16....	1.71	1.05	0.61	0.47	0.70	0.83
Aug. 2....	1.23	0.88	0.72	0.58	0.77	0.92
Aug. 21....	1.32	0.94	0.71	0.60	0.86	1.03
Aug. 24....	0.77	0.71	0.92	0.76	1.04	1.17
Oct. 5....	1.94	1.02	0.53	0.45	0.63	0.70
1907.						
May 16....	0.89	0.87	0.98	0.79	1.02	1.10
July 18....	1.65	0.94	0.57	0.46	0.71	0.85
July 20....	1.25	0.89	0.71	0.56	—	—
July 20....	—	0.55	—	0.59	—	—
Sept. 28....	0.77	0.53	0.69	0.54	0.83	0.93
1908.						
May 22....	1.42	0.84	0.59	0.45	0.71	0.85
June 15....	0.62	0.90	1.45	1.08	1.73	1.92
July 25....	1.42	0.96	0.68	0.63	0.83	0.98
Aug. 7....	—	0.70	—	0.64	—	—
Aug. 25....	1.00	0.72	0.72	0.65	0.85	1.02
Aug. 26....	0.83	0.70	0.84	0.80	1.06	1.17
1909.						
Aug. 16....	0.69	0.56	0.82	0.72	0.94	1.02
1910.						
Aug. 8....	0.80	0.61	0.76	0.58	0.88	1.03
Aug. 19....	1.30	0.94	0.72	0.60	0.80	0.90
Sept. 2....	0.87	0.41	0.47	0.40	0.58	0.65
Sept. 6....	1.45	1.06	0.73	0.56	0.91	1.10
Oct. 19–20.	0.85	0.59	0.70	0.68	0.71	0.75
1911.						
June 13....	—	1.03	—	0.67	—	—
July 17....	1.35	1.09	0.81	0.64	0.96	1.16
Aug. 15....	0.75	0.88	1.18	0.88	1.47	1.60
Aug. 30....	0.92	0.88	0.95	0.77	1.09	1.20
Sept. 11....	0.59	0.46	0.78	0.69	0.98	0.98
Nov. 6....	0.60	0.51	0.85	0.81	0.89	0.92
1912.						
Feb. 26....	1.24	1.01	0.82	0.62	1.01	1.19
Mar. 12....	1.00	0.81	0.81	0.74	0.90	1.00
Mar. 15....	1.24	0.98	0.79	0.78	0.92	1.03
Nov. 1....	0.45	0.59	1.31	0.95	1.79	1.79
Nov. 7....	—	1.06	—	0.77	—	—

*45 minutes.

TABLE 24.* — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

CHICAGO, ILL. Gagings by Sanitary District of Chicago, reported by S. A. Greeley in Jour. W. S. E., September, 1913, weir measurement of discharge.

Winnetka, Cherry Street Sewer. 381 acres, residential. Population per acre, 4.5. Impervious area, 10 per cent. District approximately rectangular, 1 x 1.6 miles. Rain gage in southwest corner of district, 3 500 ft. from gaging point. Time of concentration, 60 minutes. Limits of area tributary in 20, 30 and 40 minutes were determined.

Date, 1912.	Observed Time of Concentration. Min.	Area Tributary. Acres.	Max. Av. Rate of Precipitation during Time of Concentration. Ins. per Hr.	Corresponding Precipitation on Tributary Area, c.f.s.	Max. Flow Gaged (Excess over Dry Weather Flow), c.f.s.	Coefficient.	Remarks.
July 20	75	381	0.16	62.1	13.5	0.22	Sudden moderate shower.
July 20	50	320	0.20	64.0	15.0	0.23	12 hrs. after previous storm.
July 23	25	160	0.45	73.9	15.5	0.21	Short sharp shower.
July 28	60	365	0.15	56.2	12.3	0.22	Second of two showers.
Aug. 8	30	195	0.39	76.8	11.7	0.15	Short quick storm.
Aug. 9	75	381	0.22	82.3	13.0	0.16	8 hrs. after previous storm.
Nov. 12	20	130	0.90	116.8	20.2	0.17	Sharp short shower.
Evanston, Davis Street Sewer. Well built-up area of 420 acres; 20 per cent. impervious. Time of concentration, 40 minutes.							
May 28	45	420	0.32	134.	30.0	0.22	
June 4	15	141	0.60	84.6	11.8	0.14	
July 13	10	100	2.10	210.	27.0	0.13	
July 21	45	420	0.15	63.	10.0	0.16	
Aug. 20	10	100	0.78	78.	5.6	0.07	

TABLE 24* (*continued*). — MEASUREMENTS OF STORM-WATER FLOW IN SEWERS.

CHICAGO, ILL.

Diversey Boulevard Sewer. Area, 725 acres, 22 per cent. impervious. Population, 32.5 per acre. District, 2.4 x 0.5 miles. Very flat; many of lots are lower than streets. Time of concentration for whole area, 75 minutes; 580 acres tributary in 60 minutes. Nearest rain gage is at post-office, 4.5 miles south; next at Evanston, 8.25 miles north. Intensities used have been obtained by proportioning between these two gages.

Oct. 11	—	—	0.32	—	—	0.23	Short storm, no previous rain.
Oct. 31	—	725	0.05	—	—	0.67	Long storm, ground soaked.

Robey Street Sewer. Area, 2 513 acres; 5.6 mile long by 0.8 to 1.0 mile wide; 7.6 per cent. impervious. Population, 15.5 per acre. Practically flat; most lots are below street level. Time of concentration for whole area, 7 hours. Area tributary in storms of 2 to 4 hours, includes most of the impervious surface, amounting to about 15 per cent. of that area. Rain gage about 1 mile distant.

Sept. 21	120	580	0.13	75.4	5.0	0.07	First part of storm.
Sept. 28	120	580	0.07	40.6	6.0	0.15	Latter part of storm.
Oct. 2	180	900	0.033	29.7	5.0	0.17	Last part of long storm.
Oct. 8	120	580	0.06	34.8	3.5	0.10	First part of light rain.
Oct. 22	195	990	0.11	110.	18.0	0.16	Last shower in 6-hr. storm.
Oct. 30	210	1 080	0.034	36.7	4.7	0.13	Long, light rain.
Oct. 31	240	1 290	0.052	67.0	18.0	0.27	Last shower of a 10-hr. storm.

* From Metcalf and Eddy's "American Sewerage Practice."

Your committee is of the opinion that more will be accomplished by a larger number of gagings of small drainage areas than by attempts to gage areas of larger extent. With the smaller drainage areas the time of concentration will be less and there will be a much larger number of storms in which there can be little doubt that the maximum rate of rainfall continued at a uniform rate for a sufficient period to produce the maximum observed run-off, and accordingly, the resulting computed coefficient of run-off will be more nearly correct. In such cases, also, the difference between the computed time of concentration under conditions of maximum velocity through the sewer, and the time of concentration actually existing for any particular observation, will be slight. Moreover, in small districts, the main channels will not be large and the effect upon the results of storage in the sewers themselves will not be great.

It is not intended to minimize the value of careful gagings of the medium-sized and larger drainage areas, such as those in progress at Philadelphia. Such measurements are of great value and it is to be hoped that they will be continued. Measurements of discharge from areas of 200 to 500 acres are perhaps likely to be of most general applicability, and should be encouraged whenever it is possible to make an extended series of gagings. Where, however, the means are seriously limited and the probability of continuing gagings over a long period is not great, it is believed wiser to carry out measurements upon smaller districts from which results can be obtained in a shorter period of time. It is very much to be desired that measurements of the flow from subdistricts, which together make up a large district, whether or not the entire district is also gaged as a whole, should be undertaken as extensively as possible.

Information relating to inlet time or time required from the beginning of the rain to the moment when the flow is established at the storm water inlet is also of importance, and little or no accurate information is to be had upon this subject. We are pleased to state, however, that the city of St. Louis is about undertaking observations along this line, and it is hoped that information of much value will be available from their results in the near future.

The committee particularly wishes to express its obligation to the following gentlemen, not members of the committee, who kindly placed at its disposal the records of sewer gagings made by them: Mr. A. J. Taylor, engineer of the Sewer Department, Wilmington, Del.; Mr. Geo. S. Webster, chief engineer Bureau of Surveys, Philadelphia, Pa.; Mr. J. B. F. Breed, chief engineer, Commissioner of Sewerage, Louisville, Ky.

A bibliography relating to maximum rates of rainfall, storm-water flow of sewers, design of storm-water drains, and flood flow of streams, is appended.

Respectfully submitted,

George A. Carpenter, *Chairman*,
Harrison P. Eddy, *Secretary*,
William S. Johnson,
Hector J. Hughes,
Lewis M. Hastings,
Arthur T. Safford,
George C. Whipple,
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APPENDIX I.

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APPENDIX II.

DATA RELATING TO "SHORT TIME" STORMS.

As stated in the body of the report, the committee devoted a considerable amount of time to analyzing the records of a number of storms and the corresponding flow in the sewers from the Oxford Street sewer district, Cambridge, and the districts gaged in Philadelphia. While no results were obtained from which the committee could draw conclusions or which they consider of present value, the details are given here in order that the data may not be lost, should it appear hereafter that these figures can be utilized and trustworthy conclusions drawn from them.

In this analysis a period in each storm which contained a comparatively high rate of precipitation was particularly studied, and has been called the "significant period."

Although many of the storms considered extended over a total period in excess of the time of concentration for the district gaged, they are here referred to as "short-time" storms because the comparisons between rainfall and run-off have been made, with few exceptions, for periods of less duration than the time of concentration.

TABLE 25. — CAMBRIDGE, MASS., APRIL 23, 1909.

RAINFALL AND RUN-OFF FOR VARIOUS PERIODS.

Oxford Street District. Area, 400 acres. Imperviousness, 29 per cent.
Total run-off = .079 in. } 13 per cent.
Total rainfall = 0.59 in. } 13 per cent.
Maximum rate run-off = 0.37 in. per hr. } 12 per cent.
Maximum rate rainfall* = 0.30 in. per hr. } 12 per cent.
Time of storm, 11.30 A.M. to 3.50 P.M. = 4 hr. 20 min.

	Beginning of Period. (1)	End of Period. (2)	Length of Period. Min. (3)	Rainfall during Period. Ins. (4)	Total Rainfall from Beginning of Storm to End of Period. Ins. (5)	Average Rate Rainfall. Ins. per Hr. (6)	Average Rate Run-Off. Ins. per Hr. (7)	Maximum Rate Run-Off. Ins. per Hr. (8)
Significant Period.	11.30	11.40	10	.02	.02	0.12	—	—
	11.40	11.50	10	.05	.07	.30	.001	.002
	11.50	12.00	10	.02	.09	.12	.003	.004
	12.00	12.10	10	.02	.11	.12	.007	.009
	12.10	12.20	10	.01	.12	.06	.015	.016
	12.20	12.30	10	.01	.13	.06	.015	.016
	12.30	12.40	10	.02	.15	.12	.015	.016
	12.40	12.50	10	.02	.17	.12	.012	.013
	12.50	1.00	10			.17	.009	.010
	1.00	1.10	10	.14 in.		.17	.008	.009
	1.10	1.20	10	in 50 min. at		.17	.012	.016
	1.20	1.30	10	uniform rate.		.17	.018	.020
	1.30	1.40	10		.31	.17	.022	.023
Significant Period.	1.40	1.50	10	.04	.35	.24	.024	.027
	1.50	2.00	10	.04	.39	.24	.029	.031
	2.00	2.10	10	.03	.47	.18	.032	.033
	2.10	2.20	10	.02	.44	.12	.034	.035
	2.20	2.30	10	.02	.46	.12	.036	.037

* For 10 min. period.

TABLE 26. — CAMBRIDGE, MASS., JUNE 13 AND 14, 1909.

RAINFALL AND RUN-OFF FOR VARIOUS PERIODS.

Oxford Street District. Area, 400 acres. Imperviousness, 29 per cent.
Total run-off = .102 in. } 12 per cent. Maximum rate run-off = .080 in. per hr. } 7.0 per cent.
Total rainfall = 0.88 in. } Maximum rate rainfall* = 1.14 in. per hr. }
Time of storm, 11.15 P.M. to 1.40 A.M. = 2 hr. 5 min.

	Beginning of Period. (1)	End of Period. (2)	Length of Period. Min. (3)	Rainfall during Period. Ins. (4)	Total Rainfall from Beginning of Storm to End of Period. Ins. (5)	Average Rate Rainfall. Ins. per Hr. (6)	Average Rate Run-Off. Ins. per Hr. (7)	Maximum Rate Run-Off. Ins. per Hr. (8)
		11.15			0.00			
Significant Period.	11.15	11.25	10	.05	0.05	0.30	—	—
	11.25	11.35	10	.19	.24	1.14	—	—
	11.35	11.45	10	.05	.29	.30	—	—
	11.45	11.55	10	.14	.43	.84	.012	.023
	11.55	12.05	10	.03	.46	.18	.030	.037
	12.05	12.15	10	.12	.58	.72	.061	.080
	12.15	12.20	5	.04	.62	.48	.079	.080
	12.20	12.30	10	.06	.68	.36	.073	.077
Significant Period.	12.30	12.40	10	.13	.81	.78	.063	.068
	12.40	12.50	10	.03	.84	.18	.057	.058
	12.50	1.00	10	.02	.86	.12	.057	.058
	1.00	1.05	5	.00	.86	.00	.058	.059

* For 10 min. period.

TABLE 27. — CAMBRIDGE, MASS., JULY 3, 1909.

RAINFALL AND RUN-OFF FOR VARIOUS PERIODS.

Oxford Street District. Area, 400 acres. Imperviousness, 29 per cent.
Total run-off = .017 in. } 5.7 per cent. Maximum rate run-off = .024 in. per hr. } 5 per cent.
Total rainfall = 0.30 in. } Maximum rate rainfall* = 0.48 in. per hr. }
Time of storm, 2.00 A.M. to 7.40 A.M. = 5 hr. 40 min.

	Beginning of Period. (1)	End of Period. (2)	Length of Period. Min. (3)	Rainfall during Period. Ins. (4)	Total Rainfall from Beginning of Storm to End of Period. Ins. (5)	Average Rate Rainfall. Ins. per Hr. (6)	Average Rate Run-Off. Ins. per Hr. (7)	Maximum Rate Run-Off. Ins. per Hr. (8)
	5.00	5.10	10	.02	.04	0.12	—	—
	5.10	5.20	10	.02	.06	0.12	—	—
	5.20	5.30	10	.02	.08	.12	—	—
	5.30	5.40	10	.02	.10	.12	—	—
	5.40	5.50	10	.01	.11	.06	—	—
	5.50	6.00	10	.01	.12	.06	.001	.002
	6.00	6.10	10	.01	.13	.06	.003	.004
	6.10	6.20	10	.01	.14	.06	.004	.005
	6.20	6.30	10	.01	.15	.06	.005	.006
Significant Period.	6.30	6.40	10	.08	.23	.48	.006†	.007
	6.40	6.50	10	.03	.26	.18	.006†	.006
	6.50	7.00	10	.02	.28	.12	.004	.005
	7.00	7.10	10 }	.01	—	.03	.009	.013
	7.10	7.20	10 }		.29	.03	.018	.024

* For 10 min. period.

TABLE 28. — CAMBRIDGE, MASS., SEPTEMBER 23 AND 24, 1909.

RAINFALL AND RUN-OFF FOR VARIOUS PERIODS.

Oxford Street District. Area, 400 acres. Imperviousness, 29 per cent.
Total run-off = .096 in. } 16 per cent. Maximum rate run-off = .097 in. per hr. } 10 per cent.
Total rainfall = 0.59 in. } Maximum rate rainfall* = 0.96 in. per hr. }
Time of storm, 10.40 P.M. to 2.10 A.M. = 3 hr. 30 min.

	Beginning of Period. (1)	End of Period. (2)	Length of Period. Min. (3)	Rainfall during Period. Ins. (4)	Total Rainfall from Beginning of Storm to End of Period. Ins. (5)	Average Rate Rainfall. Ins. per Hr. (6)	Average Rate Run-Off. Ins. per Hr. (7)	Maximum Rate Run-Off. Ins. per Hr. (8)
		12.20			0.06			
Significant Period.	12.20	12.30	10	.16	.22	0.96	.003	.005
	12.30	12.40	10	.10	.32	.60	.039	.070
	12.40	12.50	10	.10	.42	.60	.084	.097

NOTE. From 1.00 P.M. to 2.20 P.M. there was a precipitation of 0.10 in. which is not included in this storm.

From 10.40 P.M. to 11.15 P.M. there was a precipitation of 0.06 in. and from 11.15 to 12.20 (a period of 1 hr. 5 min. before the beginning of the significant period) there was no precipitation.

* For 10 min. period.

TABLE 29. — CAMBRIDGE, MASS., SEPTEMBER 24, 1909.

RAINFALL AND RUN-OFF FOR VARIOUS PERIODS.

Oxford Street District. Area, 400 acres. Imperviousness, 29 per cent.
Total run-off = .152 in. } 15 per cent.
Total rainfall = 1.03 in. }
Maximum rate run-off = .086 in. per hr. } 4.9 per cent.
Maximum rate rainfall† = 1.74 in. per hr. }
Time of storm, 1.40 P.M. to 6.30 P.M. = 4 hr. 50 min.

	Beginning of Period. (1)	End of Period. (2)	Length of Period. Min. (3)	Rainfall during Period. Ins. (4)	Total Rainfall from Beginning of Storm to End of Period. Ins. (5)	Average Rate Rainfall. Ins. per Hr. (6)	Average Rate Run-Off. Ins. per Hr. (7)	Maximum Rate Run-Off. Ins. per Hr. (8)
		3.25			0.09			
‡	3.25	3.35	10	.15	.24	.90	.024	.042
‡	3.35	3.45	10	.29	.53	1.74	.052	.062
‡	3.45	3.50	5	.02	.55	.24	.074	.086
	3.50	4.00	10	.08	.63	.48	.081	.086
	4.00	4.10	10	.08	.71	.48	.074	.077
	4.10	4.20	10	.03	.74	.18	.067	.070
	4.20	4.30	10	.01	.75	.06	.059	.063
	4.30	4.40	10	.01	.76	.06	.043	.052
	4.40	4.50	10	.01	.77	.06	.029	.034
	4.50	5.00	10	.02	.79	.12	.020	.024
	5.00	5.10	10	.02	.81	.12	.016	.017
	5.10	5.20	10	.02	.83	.12	.016	.017
	5.20	5.30	10	.02	.85	.12	.018	.018
	5.30	5.35	5	.01	.86	.12	.018	.018
‡	5.35	5.45	10	.08	.94	.48	.018	.019
‡	5.45	5.55	10	.05	.99	.30	.035	.047
‡	5.55	6.05	10	.02	1.01	.12	.051	.053

* This storm preceded by storm of September 23 and 24. † For 10 min. period. ‡ Significant period.

TABLE 30.—CAMBRIDGE, MASS., SEPTEMBER 1, 1909.

RAINFALL AND RUN-OFF FOR VARIOUS PERIODS.

Oxford Street District. Area, 400 acres. Imperviousness, 29 per cent.
Total run-off =.062 in. } 16 per cent. Maximum rate run-off =.04 in. per hr. } 4 per cent.
Total rainfall =0.39 in. } Maximum rate rainfall* =0.96 in. per hr. }
Time of storm, 2.35 P.M. to 4.35 P.M. = 2 hrs.

	Beginning of Period. (1)	End of Period. (2)	Length of Period. Min. (3)	Rainfall during Period. Ins. (4)	Total Rainfall from Beginning of Storm to End of Period. Ins. (5)	Average Rate Rainfall. Ins. per Hr. (6)	Average Rate Run-Off. Ins. per Hr. (7)	Maximum Rate Run-Off. Ins. per Hr. (8)
Significant Period.	2.35	2.45	10	.16	0.16	0.96	.001	.001
	2.45	2.55	10	.06	.22	.36	.011	.021
	2.55	3.05	10	.04	.26	.24	.031	.036
	3.05	3.10	5	.02	.28	.24	.038	.041
	3.10	3.20	10	.02	.30	.12	.039	.041
	3.20	3.30	10	.00	.30	.00	.032	.036
	3.30	3.40	10	.00	.30	.00	.024	.028
	3.40	3.50	10	.00	.30	.00	.018	.020
	3.50	3.55	5	.00	.30	.00	.012	.013
Significant Period.	3.55	4.05	10	.01	.31	.06	.008	.009
	4.05	4.15	10	.06	.37	.36	.005	.005
	4.15	4.25	10	.01	.38	.06	.015	.021
	4.25	4.35	10	.01	.39	.06	.026	.030

* For 10 min. period.

TABLE 31.—CAMBRIDGE, MASS., SEPTEMBER 27, 1909.

RAINFALL AND RUN-OFF FOR VARIOUS PERIODS.

Oxford Street District. Area, 400 acres. Imperviousness, 29 per cent.
Total run-off = .081 in. } 16 per cent. Maximum rate run-off = .044 in. per hr. } 12 per cent.
Total rainfall = 0.50 in. } Maximum rate rainfall* = 0.36 in. per hr. }
Time of storm, 7.05 P.M. to 11 P.M. = 3 hr. 55 min.

	Beginning of Period. (1)	End of Period. (2)	Length of Period. Min. (3)	Rainfall during Period. Ins. (4)	Total Rainfall from Beginning of Storm to End of Period. Ins. (5)	Average Rate Rainfall. Ins. per Hr. (6)	Average Rate Run-Off. Ins. per Hr. (7)	Maximum Rate Run-Off. Ins. per Hr. (8)
Significant Period.	7.05	7.15	10	0.29 in. in 65 min. at uniform rate.		0.27	.001	.002
	7.15	7.25	10			0.27	.008	.014
	7.25	7.35	10			0.27	.018	.022
	7.35	7.45	10			0.27	.025	.027
	7.45	7.55	10			0.27	.029	.031
	7.55	8.05	10			0.27	.033	.035
	8.05	8.10	5		.29	0.27	.037	.039
	8.10	8.20	10	.02	.31	.12	.042	.044
	8.20	8.30	10	.01	.32	.06	.042	.044
	8.30	8.40	10	.01	.33	.06	.035	.039
	8.40	8.50	10	.01	.34	.06	.028	.031
	8.50	9.00	10		.34	.00	.022	.024
	9.00	9.10	10		.34	.00	.017	.020
	9.10	9.20	10		.34	.00	.011	.013
†	9.20	9.30	10	.06	.40	.36	.008	.009
	9.30	9.40	10	.03	.43	.18	.017	.026
	9.40	9.50	10	.02	.45	.12	.029	.035

* For 10 min. period. † Significant period.

TABLE 32.— CAMBRIDGE, MASS., SEPTEMBER 28, 1909.

RAINFALL AND RUN-OFF FOR VARIOUS PERIODS.

Oxford Street District. Area, 400 acres. Imperviousness, 29 per cent.
Total run-off = .143 in. } 21 per cent. Maximum rate run-off = 0.031 in. per hr. } 10 per cent.
Total rainfall = 0.69 in. } Maximum rate rainfall* = 0.30 in. per hr. }
Time of storm, 7.00 A.M. to 10 P.M.

	Beginning of Period. (1)	End of Period. (2)	Length of Period. Min. (3)	Rainfall during Period. Ins. (4)	Total Rainfall from Beginning of Storm to End of Period. Ins. (5)	Average Rate Rainfall. Ins. per Hr. (6)	Average Rate Run-Off. Ins. per Hr. (7)	Maximum Rate Run-Off. Ins. per Hr. (8)
		7.30			.01			
Significant Period.	7.30	7.40	10	0.08 in. in 1 hr. at uniform rate.		.08	.002	.003
	7.40	7.50	10			.08	.003	.004
	7.50	8.00	10			.08	.004	.005
	8.00	8.10	10			.08	.007	.008
	8.10	8.20	10			.08	.010	.013
	8.20	8.30	10		.09	.08	.014	.015
		11.55			.12			
Significant Period.	11.55	12.05	10	.01	.13	.06	.004	.006
	12.05	12.15	10	.05	.18	.30	.009	.013
	12.15	12.25	10	.01	.19	.06	.016	.019
	12.25	12.30	5	.01	.20	.06	.021	.022

		4.00			.20			
	4.00	4.10	10			.03	.002	.002
	4.10	4.20	10			.03	.002	.002
	4.20	4.30	10	0.03 in.		.03	.002	.002
	4.30	4.40	10	in 1 hr.		.03	.002	.002
	4.40	4.50	10			.03	.002	.003
	4.50	5.00	10		.23	.03	.003	.004
	5 00	5.10	10	.01	.24	.06	.003	.004
Significant Period.	5.10	5.20	10	.02	.26	.12	.004	.005
	5.20	5.30	10	.02	.28	.12	.005	.005
	5.30	5.40	10	.02	.30	.12	.007	.008
	5.40	5.50	10	.02	.32	.12	.009	.010
	5.50	6.00	10	.04	.36	.24	.012	.014
	6.00	6.10	10	.03	.39	.18	.017	.020
	6.10	6.20	10	.03	.42	.18	.025	.029
	6.20	6.30	10	.02	.44	.12	.030	.031
	6.30	6.40	10	.02	.46	.12	.031	.031
	6.40	6.50	10	.02	.48	.12	.028	.030
	6.50	7.00	10	.01	.49	.06	.025	.026
	7.00	7.10	10	.01	.50	.06	.020	.023
	7.10	7.20	10			.02	.015	.017
	7.20	7.30	10	0.01 in.		.02	.011	.013
	7.30	7.40	10	in 30 min.	.51	.02	.008	.009
	7.40	7.50	10	.01	.52	.06	.007	.008
	7.50	8.00	10	.01	.53	.06	.008	.008
	8.00	8.10	10	.01	.54	.06	.009	.010
	8.10	8.20	10	.01	.55	.06	.012	.013
	8.20	8.30	10	.01	.56	.06	.013	.013
Significant Period.	8.30	8.40	10	.03	.59	.18	.013	.013
	8.40	8.50	10	.02	.61	.12	.014	.015
	8.50	9.00	10	0.03 in.		.09	.017	.019
	9.00	9.10	10	in 20 min.	.64	.09	.021	.023

* For 10 min. period.

TABLE 33. — CAMBRIDGE, MASS., NOVEMBER 3, 1909.

RAINFALL AND RUN-OFF FOR VARIOUS PERIODS.

Oxford Street District. Area, 400 acres. Imperviousness, 29 per cent.
Total run-off = .061 in. } 14 per cent.
Total rainfall = 0.43 in. }
Maximum rate run-off = .047 in. per hr. } 11 per cent.
Maximum rate rainfall* = 0.42 in. per hr. }
Time of storm, 9.00 A.M. to 3.20 P.M. = 6 hr. 20 min.

	Beginning of Period. (1)	End of Period. (2)	Length of Period. Min. (3)	Rainfall during Period. Ins. (4)	Total Rainfall from Beginning of Storm to End of Period. Ins. (5)	Average Rate Rainfall. Ins. per Hr. (6)	Average Rate Run-Off. Ins. per Hr. (7)	Maximum Rate Run-Off. Ins. per Hr. (8)
		1.20			0.25			
	1.20	1.30	10	.01	.26	.06	.002	.003
	1.30	1.40	10	.01	.27	.06	.003	.004
	1.40	1.50	10	.01	.28	.06	.004	.005
	1.50	2.00	10	.01	.29	.06	.005	.005
	2.00	2.10	10	.01	.30	.06	.005	.005
	2.10	2.20	10 }			.03	.005	.005
	2.20	2.30	10 }	.01	.31	.03	.010	.025
†	2.30	2.40	10	.07	.38	.42	.035	.045
†	2.40	2.45	5	.02	.40	.24	.045	.047

* For 10 min. period. † Significant period.

TABLE 34. — CAMBRIDGE, MASS. *Oxford Street District.* GENERAL SUMMARY OF STORMS.

Period of concentration, 40 min. Area, 400 acres. Impervious area, 29 per cent.

Date. (1)	Duration of Storm. (2)	Total Run-Off. Ins. (3)	Total Rainfall. Ins. (4)	Ratio. Col. (3)/Col. (4) Per Cent. (5)	Maximum Rate of Run-Off. Ins. per Hr. (6)	Maximum Rate of Rainfall for 10-Min. Period. Ins. per Hr. (7)	Ratio. Col. (6)/Col. (7) Per Cent. (8)
1909							
April 23	4 hr. 20 min.	.079	0.59	13	.037	0.30	12
June 13 and 14	2 hr. 25 min.	.102	0.88	12	.080	1.14	7.0
July 3	5 hr. 40 min.	.017	0.30	5.7	.024	0.48	5.0
Sept. 1	2 hr. 0 min.	.062	0.39	16	.041	0.96	4.3
Sept. 23 and 24	3 hr. 30 min.	.096	0.59	16	.097	0.96	10
Sept. 24	4 hr. 50 min.	.152	1.03	15	.086	1.74	4.9
Sept. 27	3 hr. 55 min.	.081	0.50	16	.044	0.36	12
Sept. 28	15 hr.	.143	0.69	21	.031	0.30	10
Nov. 3	6 hr. 20 min.	.061	0.43	14	.047	0.42	11

TABLE 35. — CAMBRIDGE, MASS. *Oxford Street District.* SUMMARY OF SIGNIFICANT PERIODS.

Date. (1)	Beginning of Period. (2)	End of Period. (3)	Length. (4)	Maximum Rate of Run-Off. Ins. per Hr. (5)	Maximum Rate of Rainfall for 10-Min. Period. Ins. per Hr. (6)	Average Rate Rainfall for Entire Period. Ins. per Hr. (7)	Ratio, Col. (5) and Col. (6). Per Cent. (8)	Ratio. Col. (5) and Col. (7). Per Cent. (9)	Duration of Storm preceding this Period. (10)	Rainfall preceding this Period. Ins. (11)
1909										
April 23	11.30 A.M.	12.30 P.M.	1 hr.	.016	0.30	0.13	5.3	12	——	—
April 23	1.40 P.M.	2.30 P.M.	50 min.	.037	0.24	0.18	15	21	2 hr. 10 min.	0.31
June 13 and 14	11.15 P.M.	12.15 P.M.	1 hr.	.080	1.14	0.58	7.0	14	——	—
June 13 and 14	12.30 P.M.	1.05 P.M.	35 min.	.059	0.78	0.31	7.6	19	1 hr. 15 min.	0.68
July 3	6.30 A.M.	7.20 A.M.	50 min.	.024	0.48	0.17	5.0	14	4 hr. 30 min.	0.15
Sept. 1	2.35 P.M.	3.10 P.M.	35 min.	.041	0.96	0.48	4.3	8.5	——	—
Sept. 1	3.55 P.M.	4.35 P.M.	40 min.	.030	0.36	0.14	8.3	21	1 hr. 20 min.	0.30
Sept. 23 and 24	12.20 P.M.	12.50 P.M.	30 min.	.097	0.96	0.72	10	13	1 hr. 40 min.	0.06
Sept. 24	3.25 P.M.	3.50 P.M.	25 min.	.086	1.74	1.10	4.9	7.8	1 hr. 45 min.	0.09
Sept. 24	5.35 P.M.	6.05 P.M.	30 min.	.053	0.48	0.30	11	18	3 hr. 55 min.	0.86
Sept. 27	7.05 P.M.	8.20 P.M.	1 hr. 15 min.	.044	0.27	0.25	16	18	——	—
Sept. 27	9.20 P.M.	9.50 P.M.	30 min.	.035	0.36	0.22	9.7	16	2 hr. 15 min.	0.34
Sept. 28	7.30 A.M.	8.30 A.M.	1 hr.	.015	0.08	0.08	19	19	30 min.	0.01
Sept. 28	11.55 A.M.	12.30 P.M.	35 min.	.022	0.30	0.14	7.3	16	4 hr. 55 min.	0.12
Sept. 28	5.10 P.M.	6.30 P.M.	1 hr. 20 min.	.031	0.24	0.15	13	21	10 hr. 10 min.	0.24
Sept. 28	8.30 P.M.	9.10 P.M.	40 min.	.023	0.18	0.12	13	19	13 hr. 30 min.	0.56
Nov. 3	2.30 P.M.	2.45 P.M.	15 min.	.047	0.42	0.36	11	13	5 hr. 30 min.	0.31

TABLE 36. — PHILADELPHIA, PA., JUNE 10, 1903.

RAINFALL AND RUN-OFF FOR VARIOUS PERIODS.

District, 7th Survey. Area, 1,360 acres. Imperviousness,*
Total run-off = 0.70 in. } 42 per cent.
Total rainfall = 1.89 in. }
Maximum rate run-off = 1.33 in. per hr. } 55 per cent.
Maximum rate rainfall† = 2.40 in. per hr. }
Time of storm,

	Beginning of Period. (1)	End of Period. (2)	Length of Period. Min. (3)	Rainfall during Period. Ins. (4)	Total Rainfall from Beginning of Storm to End of Period. Ins. (5)	Average Rate Rainfall. Ins. per Hr. (6)	Average Rate Run-Off. Ins. per Hr. (7)	Average Rate Run-Off. Ins. per Hr. (8)
‡	11.00	11.10	10	.40	.40	2.40	—	—
	11.10	11.20	10	.30	.70	1.80	—	—
‡	11.20	11.30	10	.29	.99	1.74	—	—
	11.30	11.40	10	.16	1.15	0.96	0.12	0.12
	11.40	11.45	5	.08	1.23	0.96	0.49	0.49
‡	11.45	11.50	5	.10	1.33	1.20	0.18	0.18
	11.50	12.00	10	.34	1.67	2.04	0.75	1.33

* Two-thirds improved property; one-third unimproved property.

† For 10 min. period.

‡ Significant period.

TABLE 37. — PHILADELPHIA, PA., JULY 18, 1903.

RAINFALL AND RUN-OFF FOR VARIOUS PERIODS.

South Philadelphia, 3d and Lombard Streets. Area, 129 acres. Imperviousness,*
Total run-off = 0.55 in. } 76 per cent.
Total rainfall = 0.72 in. }
Maximum rate run-off = 0.98 in. per hr. } 29 per cent.
Maximum rate rainfall† = 3.42 in. per hr. }
Time of storm, 3.30 P.M. to 5.40 P.M. = 2 hr. 10 min.

	Beginning of Period. (1)	End of Period. (2)	Length of Period. Min. (3)	Rainfall during Period. Ins. (4)	Total Rainfall from Beginning of Storm to End of Period. Ins. (5)	Average Rate Rainfall. Ins. per Hr. (6)	Average Rate Run-Off. Ins. per Hr. (7)	Average Rate Run-Off. Ins. per Hr. (8)
		4.55			0.04			
	4.55	5.05	10	.02	.06	0.12	.01	0.025
	5.05	5.15	10	.01	.07	.06	.23	.36
‡	5.15	5.25	10	.57	.64	3.42	.62	.80
‡	5.25	5.35	10	.07	.71	0.42	.96	.98

* Solidly built up and paved with asphalt and Belgian block.
† For 10 min. period.
‡ Significant period.

TABLE 38. — PHILADELPHIA, PA., AUGUST 10, 1897.

RAINFALL AND RUN-OFF FOR VARIOUS PERIODS.

South Philadelphia District. Area, 105 acres. Imperviousness,*
Total run-off = 0.57 in. } 52 per cent. Maximum rate run-off = 1.02 in. per hr. } 57 per cent.
Total rainfall = 1.09 in. } Maximum rate rainfall† = 1.80 in. per hr. }
Time of storm, 9.00 P.M. to 10.50 P.M. = 1 hr. 50 min.

	Beginning of Period. (1)	End of Period. (2)	Length of Period. Min. (3)	Rainfall during Period. Ins. (4)	Total Rainfall from Beginning of Storm to End of Period. Ins. (5)	Average Rate Rainfall. Ins. per Hr. (6)	Average Rate Run-Off. Ins. per Hr. (7)	Average Rate Run-Off. Ins. per Hr. (8)
		9.50			0.07			
‡	9.50	10.00	10	0.09	.16	0.54	0.22	0.29
‡	10.00	10.05	5	.12	.28	1.44	.35	.35
	10.05	10.15	10	.17	.45	1.02	.25	.31
	10.15	10.25	10	.15	.60	0.90	.23	.23
‡	10.25	10.35	10	.30	.90	1.80	.64	.88
‡	10.35	10.40	5	.10	1.00	1.20	1.02	1.02
‡	10.40	10.50	10	.09	1.09	0.54	0.54	0.66
‡	10.50	10.55	5	.00	1.09	0.00	0.76	0.76§

* Solidly built up and paved with Belgian block. † For 10 min. period. ‡ Significant period.

§ Probably due to rainfall of 0.08 in. from 10.40 to 10.41, equivalent to 4.8 ins. per hour.

TABLE 39. — PHILADELPHIA, PA. GENERAL SUMMARY OF STORMS.

City.	District.	Area.	Impervious Area.	Period of Concentration.	Date.	Duration of Storm.	Total Run-Off, Ins.	Total Rainfall, Ins.	Ratio. Col. (8)/Col. (9). Per Cent.	Maximum Rate Run-Off Ins. per Hr.	Maximum Rate Rainfall for 10-Min. Period. Ins. per Hr.	Ratio. Col. (11) and Col. (12). Per Cent.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Phila., Pa.	Gage at So. Phila., 3d and Lombard Sts.	129	*	Unknown	July 18, '03	2 hr. 10 m.	0.55	0.72	76	0.98	3.42	29
Phila., Pa.	So. Phila., Position of gage not given	105	*	Unknown	Aug. 10, '97	1 hr. 50 m.	0.57	1.09	52	1.02	1.80	57
Phila., Pa.	7th Survey	1 360	†	Unknown	June 10, '03	1 hr. 20 m.	0.79	1.89	42	1.33	2.40	55

* Solidly built up and paved with asphalt and Belgian block.

† Two-thirds improved property; one-third unimproved property.

TABLE 40. — PHILADELPHIA, PA. SUMMARY OF SIGNIFICANT PERIODS.

City.	District.	Area.	Date.	Beginning of Significant Period.	End of Significant Period.	Length of Significant Period. Min.	Maximum Rate Run-Off. Ins. per Hr.	Maximum Rate Rainfall for 10-Min. Period. Ins. per Hr.	Average. Rate Rainfall for Entire Period. Ins. per Hr.	Ratio. Col. (8). and Col. (9). Per Cent.	Ratio. Col. (8). Col. and (10). Per Cent.	Duration of Storm preceding This Period.	Rainfall preceding This Period. Ins.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Phila., Pa.	So. Phila., Gage at 3d and Lombard Sts.	129	July 18, '03	5.15 P.M.	5.35 P.M.	20	0.98	3.42	1.92	29	51	1 hr. 45 m.	0.07
Phila., '	So. Phila., Position of gage not given	105	Aug. 10, '97	9.50 P.M.	10.05 P.M.	15	0.35	1.44	0.84	24	42	50 m.	0.07
Phila., Pa.	So. Phila., Position of gage not given	105	Aug. 10, '97	10.25 P.M.	10.40 P.M.	15	1.02	1.80	1.60	57	64	1 hr. 25 m.	0.60
Phila., Pa.	So. Phila., Position of gage not given	105	Aug. 10, '97	10.40 P.M.	10.55 P.M.	15	0.76*	0.54	0.36	140	210	1 hr. 40 m.	1.00
Phila., Pa.	7th Survey	1 360	June 10, '03	11.00 A.M.	11.45 A.M.	45	0.49	2.40	1.64	20	30	——	—
Phila., Pa.	7th Survey	1 360	June 10, '03	11.20 A.M.	12.00 A.M.	40	1.33	2.04	1.45	65	92	20 m.	[illegible].70

* Probably due to rainfall of 0.08 in. from 10.40 to 10.41, equivalent to 4.8 ins. per hour.

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PAPERS AND DISCUSSIONS

THE MECHANICS OF REINFORCED CONCRETE UNDER FLEXURE IN BEAM AND SLAB TYPES.

By C. A. P. Turner, Member American Society of Civil Engineers.

[To be presented September 16, 1914.]

The coöperation or combined action of the two materials, concrete and steel, to resist bending, depends solely on the bond between the two. In the case of plain rods this bond is in reality a shrinkage grip which prevents the steel from sliding through the hardened matrix in which it is embedded and the resistance afforded is subject to well-defined laws which may be stated as follows:

> The bond shear is zero wherever the tension in the steel is constant. It passes through zero where the increment of the moment passes through a maximum or minimum. It must be depended upon whether the reinforcement is in one direction only as in a beam, or in multiple directions in the slab.
>
> Bond shear generates stresses emanating from the surface of the bars which may be treated as lines of force. These lines of force follow the general laws of distribution of force through any medium; that is, their intensity is inversely as the square of the distance from the surface of the steel on which they are generated.

These general laws enable us to investigate or follow out the part played by bond shear in the mechanics of a slab or beam.

Note. This paper is issued in advance of the date set for its presentation. Discussion is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before November 10, 1914, for publication in a subsequent number of the Journal.

In the case of a simple beam, in accordance with the law stated, the intensity of the bond shear is zero at the center for uniform load and a maximum toward the end of the beam, and it is the bond shear or the lines of force generated thereby to which we may attribute the difference in the failures of an over- and an under-reinforced beam. In the case of the beam with light reinforcement, failure takes place at the center by the yielding of the steel. With heavier reinforcement, however, failure is more liable to occur toward the end by diagonal tension induced by web stresses, which are greater toward the ends of the beam and which may rupture the concrete across the lines of tension in it. Perhaps the largest part of these web stresses originate in the bond shear at the surface of the reinforcement.

The deportment of the simple beam as affected by the stresses set up by the bond shear is of interest. In a newly cast beam, in the preliminary stages of the loading, the stress in the steel as determined by the extensometer, is much less than that figured on the assumption that the steel only resists tension. In fact, it is only about one half as great as we should compute the stress to be on that basis, until the steel is stressed up to four or five thousand pounds per square inch. When this point has been reached there is a rapid increase in the stress in the steel, with no corresponding increase in the load until, when the steel is stressed up to twelve or fifteen thousand pounds per square inch, the concrete has relieved itself of a large portion of its tensile resistance and the measured stress in the steel corresponds closely to the computed stress in the steel, assuming that the steel is not assisted by the concrete in tension.

With the slab reinforced in two directions, however, the phenomenon differs from that observed in the beam. Take for example the case of such a slab, bent in such manner that the rods in both directions are brought into tension at the same time. The indirect stresses generated by the two sets of rods will, under this condition, react upon each other, since the lines of force diverge from each rod they may meet, and coact through the concrete as a medium of transmission of the stress, which is not possible in the beam with one-way reinforcement, since in the beam these stresses cannot coact with each other, there

being one kind only, and not two kinds acting in different directions. This fundamental difference in the induced stress generated by the bond shear in the case of a beam and slab render the two types of structure mechanically different, and necessitates their treatment in a manner which takes into consideration the difference in the mechanical operation of the indirect stresses referred to.

A crack in the slab would not materially interfere with the operation of these indirect stresses in each segment of the multiple-way reinforced slab, while a crack in a beam normal to the direction of the steel would intercept any indirect tensions induced by the bond shear at the section checked, and prevent the accumulated resistance afforded by these indirect stresses from being effective in direct resistance to moment.

In treating the combination of the two materials, it has been customary to consider their combined action as determined by the elastic properties of each taken separately, that is, by considering the ratio of the modulus of elasticity of the concrete in compression and tension to the modulus of elasticity of the steel in tension and compression. In a homogeneous elastic slab, such as steel in the form of a plate, there would be taken into consideration in addition to the modulus of elasticity of the metal in tension and compression in one direction, the additional coefficient of modulus of lateral deformation known as Poisson's ratio. This ratio, or lateral effect, in a combination of steel and concrete which is sufficiently fine-grained to be regarded as acting like a homogeneous material, as is the case with reinforced concrete slabs, cannot be correctly considered as an elastic property of either the concrete or the metal, but on the contrary must be treated as a coefficient expressing the efficiency of the lateral action of the indirect stresses induced by the bond shear in the case of multiple way-reinforcement in the slab, which coefficient, for the reasons above explained, must be zero in the case of the beam type, with reinforcement in but one direction, or the case of the slab in which the reinforcement under strain runs in but one direction only. Although transverse reinforcement may be introduced in a beam, it can perform no useful function in reducing the stress on the carrying-rods, since the

indirect stress induced by one series of rods under strain cannot converge to react upon another set of rods not under stress, but can react with that set of rods only when both are generating indirect lines of force arising from bond shear.

The indirect stress from bond shear to be depended upon, must react upon other indirect stress and be held in equilibrium by these stresses generated by the steel. Otherwise, we are depending upon the direct tensile resistance of the concrete for bending, which is not considered permissible by those experienced in reinforced concrete design.

In the case of the beam with one-way reinforcement, there is no way for these stresses to react upon each other and be held in equilibrium by each other. The slab, however, furnishes a condition by which this desirable end is obtained.

The law governing the generation of bond shear indicates clearly that if this element of strength is to be utilized, wide-spreading reinforcement must be used. Otherwise, its efficiency is negligible. This law eliminates from consideration as an economic and successful flat slab, any arrangement of narrow belts or strips of reinforcement in a flat slab of uniform thickness which does not permit, by virtue of the arrangement, efficient operation of the forces outlined.

That the performance of a flat slab with multiple-way reinforcement is essentially different from the mechanical operation of one-way reinforcement in a beam is apparent if we consider that as a mechanism its operation is governed by the fundamental law known as the law of conservation of energy and its various corollaries. As a substantially elastic structure — and we are dealing with an elastic theory — the external work of the load must equal the internal work of deformation. It is true, of course, that the slab is not perfectly elastic because of shrinkage stresses, and because the concrete does not completely fulfill the conditions of a perfectly homogeneous elastic solid, but when the slab is thoroughly cured and of good concrete, its deportment for practical purposes may be treated on this basis.

The utility of the flat slab, as compared with beam construction, depends on lateral resistance, enabling the same resistance to be secured with a smaller thickness.

"The external work of the load equals the internal work of deformation, or the product of the force multiplied by the distance through which it moves is a measure of the internal work of resistance of the structure withstanding this force."

This statement (Clapeyron's Theorem, 1866*) gives a basis for ascertaining the manner of the storage of potential energy in a reinforced concrete structure by which can be demonstrated the difference between the circumferential cantilever action, as in a Turner slab, and the lineal cantilever action, such as that of Hennebique, of the beam type. In considering this matter we will assume a Hennebique structure with the slab of the same thickness as the Turner floor-slab, and assume the same amount of cross-section of steel in the two cases.

Since the steel runs in multiple directions in the belts of Turner, having substantially uniform spacing, and since the material is strained circumferentially as well as radially, and in such a way that the circumferential and radial deformation must, from the geometry of the slab, be equal, it can be shown that the energy stored circumferentially about the cantilever head in the belts of rods is equal to that which is stored radially. Now if half our energy is stored circumferentially and half radially, it is evident that while the circumferential deformations are coincident with, and their magnitude dependent on, the radial deformations, it is the radial deformations or extensions along a meridian line which determines the vertical geometry of the slab. In other words, as half our energy is stored circumferentially, we have established a different method of storage of energy in the circumferential cantilever of Turner from the lineal cantilever of Hennebique. In the lineal cantilever no energy can be stored circumferentially, because the steel does not run in that direction; there is no reservoir, so to speak, in which to store it.

Suppose we assume that the same quantity of energy (symbolizing it by Q) is stored in each respective structure. Then, if the load be applied gradually, and we use W_1 to represent the load and H_1 the mean deflection of the lineal cantilever, we have

$$Q = \tfrac{1}{2} W_1 H_1 = \tfrac{1}{2} W_2 H_2,$$

*See Lamé "Lecons sur la théorie mathématique d'élasticité de corps solides."

W_2 and H_2 referring to the load and the deflection, respectively, of the circumferential cantilever. Now, if half the energy in the circumferential cantilever is stored circumferentially, and half radially, and that stored circumferentially produces no deflection, then $H_2 = \frac{1}{2}H_1$. That is, the mean deflection of the circumferential cantilever, represented by H_2, is only one half the mean deflection of the lineal cantilever, represented by H_1. Likewise, Q being the same for each, $W_2 = 2W_1$. But if we assume for purposes of closer comparison that the deflection be the same with each, instead of the quantity of energy stored being the same in each, then W_2 (the load of the circumferential cantilever) must equal $4W_1$ or it will require *four* times the load to produce the same deflection with a circumferential cantilever, it being assumed, of course, that the same amount of steel is used that it will require with a linear cantilever in each, and that the same depth of slab is employed.

From this relation of the storage of energy, it is evident that a circumferential cantilever and suspended span slab of half the thickness will present the same rigidity as a continuous beam construction of double the depth, being a measure of the difference in deportment of beam action and slab action.

Bending Moments. — Regardless of the manner in which the load is carried to the support, it is an invariable or fundamental law for uniform loading that half the sum of the bending moments over the support, plus that at mid-span, equals a constant, equals $\frac{1}{8}WL$. This is true for a continuous beam, simple beam, a continuous slab, or a simple slab, or one fixed at one end and free at the other. From this relation we would have for a slab of indefinite extent, supported at points, as the magnitude of the moment at the support, $WL/12$, and the moment to be resisted at the center, $WL/24$, and we are now in position to consider the modification due to the size of the capital. For the usual proportions this would reduce the moments just given to $WL/15$ and $WL/30$, respectively, for a single panel, but in the cantilever portion about the column these external moments or apparent moments, as Dr. Eddy treats them, are resisted in two ways — by true moments, in the steel radially, assisted by the bond shears coacting

with each other and by true moments in the steel circumferentially, also assisted by the bond shear. Thus the radial moment in a line at the critical section about the cap to be resisted would be $WL/30$, which in the mushroom type is provided for by the combined radial rods and slab rods.

In the discussion thus far I have dealt generally with slabs of uniform thickness, and it is in order now to make a few remarks applicable to slabs not presenting this characteristic — that is, with a thickening up of the concrete at the column.

The general principle of rigidities must apply to this case. This principle may be stated as follows:

> Where there are two or more paths by which the load may travel to the support, the load divides itself between the paths in proportion to their rigidities.

Increase of the rigidity of the cantilever portion throws the line of inflection outward, increasing the moment at the support and decreasing the moment at mid-span to the extent that the load is a balanced load and the column rigidity permits its action in this manner. As the writer views this modification of the slab, it is not an altogether desirable modification, for the reason that it involves increased bending at the column, a large increase in the apparent moment to be resisted over the support, decreased toughness and ability to resist unbalanced load.

In my preceding remarks I have pointed out the comparative stiffness and strength of a linear cantilever and a circumferential cantilever. It is next in order to show that in the suspended span-portion covered by crossed belts in a diagonal direction, the same relation holds true because of coaction between the two belts. In the direct belt there is no such action at the center. The moment there, however, is reduced by the stress in the diagonal belt crossing and assisting it where there are four belts used. This assistance in the standard mushroom design with the proper width of belt, half the distance between columns, will amount to practically six- to seven-tenths of the efficiency of the direct belt, so it is evident that, if the diagonal reinforcement is to be eliminated, the side-belts must be increased very largely or to nearly double the cross-sectional

area required for the four-way system. This increase is brought about not only by reason of the relation just pointed out, but for the further reason that with a four-way arrangement, the resistance to circumferential stress by the steel is more complete than with a two-way arrangement.

In a short paper of this kind, a complete discussion of all phases of the problem would be beyond its scope. To point out the fundamental difference between beam action and slab action and to offer a simple explanation thereof is the object which has been aimed at. Of the large amount of work which has been constructed giving perfect satisfaction, there is required some explanation more consistent and rational than to say that the uncertain and unreliable tensile strength of the concrete has brought about such satisfactory result. For those who are inclined to consider that the direct tensile strength of the concrete can be credited with these results, such experiments as the writer has made, in which the slab when loaded carries the load by concrete tension very well at first but in the course of a week or ten days failed completely under the load, would carry conviction to those who would take the time to investigate. The difficulty, as the writer views it, of arriving at a scientific analysis of the slab, has been the confusion of the properties of a composite material with those of a homogeneous elastic body.

Reinforced concrete is not a homogeneous material, but consists of radically different elements, steel and concrete. The properties of these materials are radically different. They work together only by virtue of the bond shear or shrinkage grip between the two, and it is the property of this connecting link or lateral efficiency thereof which has been successfully treated as Poisson's ratio by Dr. Eddy in his mathematical analysis of the continuous flat plate.

The Poisson ratio with which Dr. Eddy deals, as I understand it, is not a property of either concrete or steel, and has absolutely no relation to any property of the two materials, but is nothing more nor less than the coefficient of the lateral efficiency of the indirect stresses induced by bond shear in their coaction with each other, which coaction occurs in such manner that the direct tensile strength of the concrete is not overtaxed,

as would be the case where dependence is placed upon the energy stored by indirect stress in a one-way reinforced beam.

The difference in operation of one-way and two-way structures as machines for storing up of the energy developed by the load in its descent during deflection of the slab, is of interest. In a newly cast beam, the deflection for small loads is much less than we would figure by the ordinary theory. The energy stored by the indirect stresses arising from bond shear in tension, however, is not stored in a stable manner, because the concrete soon becomes overtaxed or cracks, and energy thus stored leaks away and is dissipated. Further energy is developed by the load in its further descent through increased deflection, which is stored in turn by the steel. This phenomenon is sometimes incorrectly described as the concrete relieving itself of the stress and throwing it upon the steel. As a matter of fact, no such interchange occurs. The energy stored in the concrete is lost and dissipated and new energy is developed by the load in its descent through increased deflection, which energy is stored up in the steel in a dependable manner. In the slab, on the contrary, where energy is stored by the coaction of one set of indirect stresses with another, the storage is a dependable one, for the reason that these stresses are not cumulative, since they are merely transferred through one set of rods to the other through the concrete as a conductor, and do not have any cumulative effect on the structure, as in one-way reinforcement.

Certainly a theory such as that of Dr. Eddy, which enables us to compute deflections accurately, and which gives the steel stress in accord with experiment, cannot be lightly dismissed, no matter with what disfavor Poisson's ratio, the basis of the computation, may be viewed.

In conclusion, I believe that a clean-cut understanding of the nature of the fundamental relations which I have pointed out may help clear up some of the mystery with which slab design has been obscured, and that a more complete discussion of the fundamental laws of mechanics applicable thereto will eliminate the many errors and inconsistencies in its design into which those have fallen who have given the subject insufficient study. One of the gravest mistakes and the most common one, has been

that of using too high a percentage of steel, with the confident belief that this excess of steel would add materially to the strength of the structure. The performance of the scientifically designed flat slab under test, places the burden of proof upon the critic, to show wherein the method of design is in error, and it would seem that thus far all criticism of the successful flat slab had been based upon the gratuitous assumption that reinforced concrete is such an anomalous mechanism that its operation as a machine is totally independent of the law of conservation of energy and the principles of least work. Further, our critics would have us believe that its innumerable manifestations of strength should cause us to lose all confidence in the dependence usually placed on the law of gravitation as a proper basis for load tests.

Treating the scientific flat slab as a machine on the theory of work, we can readily check up Dr. Eddy's conclusions regarding the performance of the machine in respect to its deflection. We have shown that the circumferential cantilever is four times as stiff as the linear cantilever. Now the successful flat slab is a continuous construction and it would be four times as stiff as the continuous beam. The continuous beam, in turn, is five times as stiff as the simple beam. Hence, the continuous flat plate is twenty times as stiff as the simple flat plate, but in order to build a flat slab supported on columns we have to have support of, generally, two tenths of the span in diameter. This reduction of the span to eight tenths would render the slab forty times as stiff as a simple slab on knife-edge supports, were it not for the fact that the resisting section grows smaller in a continuous slab on posts as the post is approached. This difference reduces the relation from forty to approximately thirty times for the above ratio of metal to span.

It seems to the writer that the average structural engineer, in the consideration of his structures, is more inclined to feel that he is dealing with a mere problem of static equilibrium than to consider the structure as a true machine in which all of the elements are put in motion by every change of load.

Looking at it in the true light of its operation as a machine, or mechanism, the theoretical error of disregarding the vital

elements or parts of the machine in treating its operation becomes apparent. We would not consider it practical to expect satisfactory operation of an engine with the connecting-rod left off, and why should we consider any theory as applicable to the operation of the flat slab in which the connecting link between the concrete and the steel is left out of consideration? Such a theory must evidently be as unsatisfactory in application as the engine with the connecting-rod removed.

Failure to consider the continuous flat slab as a mechanism accounts for the strange misconception of its character by the great majority of the engineering profession. They look at the commercially successful flat slab as one which is merely flat on top and bottom. Certainly the writer was not a pioneer in flat-slab construction of this ancient and useless variety.

In the construction of the reservoir at Bridgewater, Mass., a slab flat on top and bottom was used, and strips of expanded metal marked " lintels " on the working drawing were stretched from column to column in two directions and expanded metal was spread in the bottom layer. The operation of this structure as a machine, however, would not be the mode of operation which I have outlined by the preceding theory of work. It is a different mechanism entirely. No useful circumferential action could occur in the upper zone about the column, while the difference in rigidity of the expanded metal in the two directions, longitudinally and transversely, would prevent any material circumferential resistance in the bottom between columns. The performance of other slabs, flat in form as machines, may be referred to here.

Mr. George Hill of New York, in the *Architectural Record* of September, 1902, described the construction of a warehouse with columns 16 feet centers, slab 11 inches thick, designed to carry 400 pounds working load, or 52 tons per panel. Failure occurred under approximately half this supposedly safe load, and the floor is now supported on alternate brick piers and concrete posts 8 feet centers, or nine times as many points of support per panel, 16 feet square about the column, as originally designed.

A reservoir roof on a similar plan was attempted, with columns about 22 feet centers, slab between seven and eight

inches thick. Instead of seven posts it now rests securely on somewhat over forty posts.

The performance of these structures as machines when the thickness of the slab is reduced so that stability must depend on the slab action was unsatisfactory, for the reason that the general laws necessary to secure satisfactory results were not complied with. The type of flat slab outlined in Taylor and Thompson's work would come somewhat under the same category as regards width of belt and proper distribution of the material over the columns, to secure the most effective reduction of the radial moment by circumferential action. Its glaring defects in this respect the writer has noted with surprise, but they seem not to be generally appreciated by the profession at large.

To undertake in a short paper the discussion of wall panels, column flexure, and other more intricate phases of the flat slab problem, while as yet the simplest and most elementary form of the problem, the interior panel, is not generally understood, would be, as the writer views it, a waste of effort. When there is more general agreement on the simplest form of the problem, then the more complex and interesting phases of the question are in order for discussion.

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BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

PAPERS AND DISCUSSIONS

DISCUSSION OF "BOSTON FOUNDATIONS." PRESENTED AT THE SPECIAL MEETING OF FEBRUARY 25, 1914.

MR. T. W. CLARK. — The only thing I have to say is that we have driven about thirty jobs in and around Boston and have been trying to collect data on borings to prepare a tabulated sheet showing the results of our driving, the length of piles, penetration, number of blows, etc., and also the depth of borings, showing where the hard material is. We have been unable to get this ready for to-night, but hope to submit it so it can be embodied in the proceedings. I might say we have driven about 156 000 linear feet of piling around Greater Boston, — that is, about 6 000 piles.

MR. H. F. BRYANT. — My thoughts on this subject came after and not before the last meeting. After attending that meeting I thought the matter over and the next morning I dictated my discussion. I do not think there is anything particularly new in it, but there are one or two points I have sought to make. I do not know that I need to bring them out here, but if the editor has room in the forthcoming JOURNAL he is at liberty to publish them. I would like to say one or two things while I am on my feet in regard to the discussion this evening. There is a question-mark in my mind about that grade 8 or grade 13 for the cutting off of piles at the new Technology. I am curious to know (if anybody does know) why the ground water should be higher on the Cambridge side of the basin than

on the Boston side, and, if it is higher on the Cambridge side, can we expect it to remain higher? I do not believe it would be safe to cut off the piles at grade 8 on the Boston side. While I do not criticize anybody for believing that it is proper for the Cambridge side, I have curiosity to know why anybody should think the conditions are different on that side than on the Boston side. I rather feel that 5 and 6 are pretty good grades to cut off at in the Back Bay Fens and the district thereabouts. I think Mr. Main is absolutely right, and I think perhaps this has not been mentioned by anybody else, in saying that it is unwise to depend on the bearing power of the point of spruce piles. I do not think I have ever done this, and I should be sorry for any one who only had the point of spruce piles to depend upon for carrying power. I see a good deal of driving done where there is less than a foot of penetration into the bearing soil and the piles are left that way to carry the load. The buildings have not gone down, but some of them have cracked badly, and I believe it is due to the fact that the piles were overloaded rather than to the settlement of the soil.

Mr. Gow said a word in favor of a double row of piles in foundation walls. I have practiced using a single row of piles capped with concrete masonry. I do not think this construction is fit to use with any other type of masonry, but during the last fifteen or twenty years, I have used single rows of piles and I have never seen anything that leads me to believe it is unwise when there is a concrete foundation on top properly reinforced and thoroughly tied together. If there is any case where it is unwise, I should be very glad to know of it. It is often a great saving in cost and there is a better opportunity to distribute loads where a double row is used.

Mr. Gow mentions the wisdom of stopping the piles in the stiff crust which we find so frequently in the Back Bay, but as we often find that the stiff crust is only a foot or two thick overlying the clay, I prefer to put the point of the pile 10 or 15 ft. below that crust and not depend upon the point at all. Then, if you please, put 15 to 18 tons on those piles, rather than have a larger number of piles and stop them on the crust, I do not know that many structures would fail to stand up if the

piles stopped on the crust, but I have done it the other way and have never had any trouble.

MR. CHAS. R. GOW. — Answering Mr. Bryant's query about ground-water level on the two sides of the river, I think perhaps he may not have it in mind that grade 13, Cambridge base, is the same as grade 8, Boston base, and therefore the water levels are the same. When the city of Cambridge first established the base, they had in mind using the readings for sewer grade work and wished to escape a negative reading, and they therefore ran their base from the Charlestown Navy Yard, as we have in Boston, but took our —5 for their zero in order to escape some of their minus readings. In that connection, however, I failed to state that in the test bearing which we made and which I referred to, at the corner of Albany and Portland streets, which is probably not more than a quarter of a mile from the basin, — we found the water at grade $9\frac{1}{2}$, Cambridge base, or considerable below the ground water of the basin, and the inference is that the ground water of that locality has escaped along the line of the Metropolitan sewer trench or some other outlet, and it illustrates the fact that the same thing is true in Cambridge that we find in Boston, — that no constant water level can be depended upon unless we go to a considerable depth.

MR. F. H. FAY. — The point was brought out that the ground-water level close to the bank on the Boston side of the Charles River basin was below the level of the basin, and that is due probably to a certain extent to the construction of the sewer being close to the basin wall. Now, the question arises, What would happen if a similar sewer should be established on the esplanade on the Cambridge side? Would it not be lowered below grade 8 according to the evidence that has been presented in regard to the Boston side? Has that been taken into consideration, Mr. Main, — the question of the possible construction of a sewer on the Cambridge side?

MR. C. T. MAIN. — I think not. The basin is at grade 13, and the water level all over the Technology site is at grade 13, but it was desired by some of the parties to cut the piles off at a level higher than 13. It was decided the other day, however, that nothing should be any higher than grade 13.

Mr. Bryant. — I would like to mention one thing, — that is, the appearance of these piles. In a building over at the corner of Oneida St. and Harrison Ave., I found a pile whose top was at perhaps grade 14, seventy years old, as sound as it ever was, — apparently a spruce pile. It was pulled up, and from top to bottom it was sound. A neighboring pile — two years old — of spruce, not more than fifteen feet away, the top of which was at grade 12, had two or three feet at the top absolutely gone.

Mr. Clark. — In reply to Mr. Bryant's statement about driving piles into the firm bearing material, it has been our practice to drive at least 2 ft., provided we have 3 ft. of sand or gravel below the point of the pile. Very often we have punctured the upper crust and driven 8 to 10 ft. into the clay in order to get the necessary support. We are allowed to carry thirty tons on the piles by the Boston building department, and the majority of tests show practically no settlement under these conditions.

Mr. Fay. — In other words, a crust 5 ft. thick as a minimum is considered. Anything less than that you expect to penetrate, but with anything over that you expect to stop your piles on that course.

Mr. Clark. — Yes. We try to determine that by borings which are given us before we start. When we do not have these, we generally drive a long pile to determine the conditions.

Mr. J. E. Carty. — That is on concrete foundation, of course?

Mr. Clark. — Yes. I stated that it was on concrete.

Mr. Gow. — While we are speaking of that subject, I would like to state that the suggestion came to my mind through some sewers in the Cambridge district where we have this condition of a blanket of fairly coarse gravel over a stratum of very soft clay; and I think there is a divergence of opinion among engineers and architects as to whether piles should be stopped in this gravel or driven through into the clay. I find there is a prejudice in the minds of some engineers as to the utilization of gravel and sand in stopping a pile. Some prefer to go to the clay in any event, under the assumption that they get better

results from friction, etc., in clay, and as a result we have not tried to drive spruce piles through this stratum into the clay. Until we penetrate the blanket we have most difficult driving, but once the soft material is entered it will go ahead a foot at a blow almost indefinitely. We sometimes have these conditions in Boston proper. In some sections of the South End, after driving through silt and peat, we strike a blanket of rather stiff clay which, if it is penetrated to a sufficient depth, will change into soft clay in which the piles seem to develop no resistance whatever, and my observation, which I referred to in the paper, had reference to such a condition as that, — whether it would not be better to take advantage of the stiffer medium on top and use that to distribute the load of the pile over a wider area of the soft underlying soil rather than drive it into the softer underlying soil and depend upon the friction.

Mr. L. B. Manley. — One or two things that the construction of the Boston subway brought out perhaps deserve mention here. This gravel and sand to which so much reference has been made has been found running westerly from Exeter St., and we found it to be an exceedingly good material. It is rather fine on the top and grows coarse toward the bottom. There has been from 5 to almost 20 ft. in depth at some points. There are places where we have dug up underneath the buildings along Newbury St. and found that the buildings had been supported on piles, and the piles had penetrated very little into the gravel and yet they are holding up the buildings without any sign, or with very little sign, of cracking. This gravel is strongly water-bearing, and I have an idea that the distribution of the water over this part of Back Bay may be effected through that layer of gravel. Another thing Mr. Gow spoke of which interested me was in regard to the possible settling of the ground due to the compacting of the clay. We have found that the clay for its upper ten feet has been hard enough to require the pick to remove it. The excavation for the subway has not penetrated this upper ten feet, but, from borings and from the results of piles which have been driven down, we are led to believe that the lower ninety feet of this clay is very soft, and it is quite disheartening to see a pile go down through that soft

clay. I fully believe that if you have a strong bearing in gravel your pile is going to hold up fully as well as though it went a moderate distance into that clay. But there is another matter which might be brought out and which has been undoubtedly noticed by every one who has driven piles into this clay, and that is that while it appears to be going down at a very fast rate (perhaps six inches at a blow), if you let that pile set over night or even during the dinner hour and try the hammer on it again, it has been set up by friction so that it will hold and will require two or three blows to get it going again.

Mr. A. O. Doane. — Some few years ago I had a little experience in Cambridge with the subsidence of the ground-water causing piles to rot. A large main of the Metropolitan Water Works broke in Harvard Sq. on Christmas eve, 1909, and a large quantity of water escaped which flooded the cellars of many buildings, among others the municipal building in Brattle Sq. A few days after the occurrence, some of the city officials thought that the building was settling as a result of the flood, and pointed out cracks in the wall which they said had opened. I thought the cracks looked old, and could not exactly connect a few feet of water in the cellar with such a sudden settlement of the building. So I did some investigating and found that the building was supported on piles, and that some five or six years before this it had been necessary to remove the foundation under the westerly side of the building, which was the side that was holding up all right, cut off the piles and build it up again. In view of that, we refused to believe that the settlement was entirely the fault of the break in the main. It is possible that the water coming in there may have accelerated it a little, but there was every evidence that the cracks had been there for some time, and that the building had settled gradually. The city of Cambridge employed a contractor who dug down and took out the heavy rubble wall down to the tops of the piles. Then it was found that the upper foot of the piles had rotted almost completely away, and this was sufficient cause for the settlement of the building. The piles were cut off about two feet down and the wall rebuilt. There has been no trouble since. It was evident that for some reason the ground-water level had

been permanently lowered. If that condition obtained there, I should think it might obtain in some other parts of Cambridge.

MR. FAY. — Do you know what the grade was at the tops of those piles?

MR. DOANE. — These piles were originally cut off at elevation 9.45, Boston base. The elevation of the ground-water on March 18, 1910, was 8.20. I was informed by a Cambridge builder that when the foundation was put in for this building the piles were cut off well below the level of the ground water.

MR. E. W. HOWE. — The last speaker brings up a point which I have not heard mentioned in this discussion, and that is the grip of the filling around piles forcing the pile down as the filling settles.

I recall an instance of this in the small artificial island at the end of the pleasure pier at Marine Park, South Boston. An island was built, upon which it was originally intended to erect a structure several stories in height. The island was filled with gravel to grade 15, the original surface of the flats being at about —7, below which there was about 20 ft. of mud overlying a hard yellow clay. After a portion of the filling had been deposited, piles were driven and cut off at grade 5, and masonry laid for a foundation of the intended building. This masonry made a very light load on the piles, yet in a year or two it settled about 2 ft. The island and the masonry maintained its shape and there was no other effect than the change in grade of the surface.

The same result took place at the shore end of the pier, where several years before a wooden pier on oak piles had been built. Until filling was deposited here there was no settlement of the piles. When, however, after the pier had stood several years, the area which it occupied was filled with gravel, the settlement of the gravel carried down with it the large oak piles which had previously been firmly driven into the hard yellow clay.

MR. CARTY. — One thing I think has not been brought out very strongly to-night, and that is the fact that sewers built below the level of ground-water sometimes lower that level. The sewer trench itself acts as a drain, and the water will be

lowered by that drain. Immediately after a sewer is built the ground water will be lowered a good deal and will then come back; but I have seen many cases where the ground water has been lowered quite a bit permanently; and I think that ought to be emphasized.

Mr. J. R. Worcester. — I have one or two questions which I would like to ask of the speakers to further increase the value of their remarks, if possible. In the first place I should like to ask Mr. Clark if he will tell us what formula he uses in determining the value of his piles. He said that in some cases where they had penetrated through the crust they were obliged to go to a certain depth of clay in order to get the sustaining power. That implies that he must have some formula or some method of determining how much depth will be necessary in order to get the strength which he figures. I would like to ask Mr. Main if he would be kind enough to tell us what increase on loads on foundations he has reached in his later practice. He gave the units which he adopted many years ago, but said that later he has used some higher limits. I would like to know to what extent he has done that. I want also to refer to one point in Mr. Adams's discussion which is quite important.

It does not seem as if anybody would be so foolish as to figure on the sustaining power of soil around piles in addition to the sustaining power of the piles themselves. Mr. Adams says he did not do it on the Fish Pier and that reminds me of the fact that I have run across instances where that has been done and has been allowed by people in authority who ought to know better. The fact that piles are driven so closely together that it is even doubtful whether there is a sufficient area of soil below each pile to support the pile is not the whole of the objection to the practice, but the other point is that if we use piles at all we do it because there is a certain depth of soft material overlying the hard material, and the soft material is bound to settle away in the course of time and leave voids around the pile heads. I also want to ask the question generally, not only of those gentlemen who have spoken on this question, but of everybody else, — whether they have any evidence of any pile having rotted below grade 8. We have heard a good deal about

water levels being found lower than grade 8, but neither in my observation or that of anybody I have talked with is there an instance of a pile rotted below grade 8. Mr. Bryant has referred to one cut at grade 12, of which possibly there were three feet rotted, which brings it to about grade 9. In the district east of Harrison Ave. and south of Beach St., many of the piles of the original buildings were cut at grade 10. The tops of many of these are rotted quite badly, but I have never yet seen actual destruction of the pile as low as grade 8. I have followed the discussion, especially this evening, and have not yet heard reference to an instance of that kind, with the possible exception of that mentioned in Brattle Sq., where the speaker did not know exactly what the grade was. I think it would be quite important to determine that. It seems to me that considering the age of many buildings in Boston built on piles, if grade 8 is a dangerous level we should know it by some experience, and I trust that if anybody has had any experience along that line he will bring it up.

Mr. Fay. — I would ask Mr. Clark what answer he can make to that.

Mr. Clark. — We are governed entirely by specifications which are given us by the engineers and architects. Most of these are *Engineering News* formula. Our instructions to our foremen are to follow the tables which are given us. They have so far proved satisfactory.

Mr. Main. — Each case is treated by itself and the load determined after examination. I should say, roughly speaking, that I had increased the loads fifty per cent. from what I gave in the discussion.

Mr. Fay. — Has anybody present any evidence of the decay of piles below grade 8? Mr. Bryant, have you any experience in that direction?

Mr. Bryant. — I have only one case in mind, and I am not very sure of my data. There is a certain house on the Back Bay where I found the piles rotten. I made this investigation before I made any investigation of ground water in the Back Bay. My recollection is that the piles were put in in the early days before there were any reauirements that they be cut

off at grade 5, — when they were cut off anywhere from grade 9 to grade 6, and I do not know but higher than grade 9. There was considerable evidence of decay in those piles, but we left them there and the house is still standing. I think perhaps there were one or two extra piles put in. I am very clear, however, that there were evidences of decay that looked as if they might continue for a foot or two at the top of the pile.

Mr. Doane. — In the case which I spoke of, though I do not recall the height of the piles, I think I can get that information, and shall be glad to do so.

Mr. Gow. — I neglected to state in my previous remarks that I had taken a reading on the ground-water level in the test boring at Albany and Portland Sts., Cambridge, and found that it stood at grade 9.5, Cambridge base, or 4.5, Boston base. The location of this boring was within one-third mile of the Charles River Basin, where the water constantly stands at grade 13.00, Cambridge base. I believe there is a comparatively free source of communication between the subsoil at this point and the waters of the basin through the sand and gravel strata underlying the intervening territory, and it would naturally be expected that the water level of the basin would determine the ground-water level at the site of the boring.

Whether the water in this locality escapes along the line of the Metropolitan Sewer, or in some other direction, the fact remains that it is apparently unsafe to place too much reliance upon the naturally expected level of ground water in any locality when fixing the cut-off point of wooden piles.

The grade 8.00 cut-off suggested by Mr. Worcester has not of course been demonstrated as yet to be unsafe, but it must be remembered that in but comparatively few instances have piles been cut at so high an elevation as 8.00, and hence there has been little opportunity afforded for a study of the consequences. Again, it should be noted that in general the ground-water levels of the past have been higher than those of the present, and therefore while such a higher grade might have been safe for the cutting of piles in former times, there seems to be abundant evidence that it may reasonably be expected to prove unsafe for the future.

It will undoubtedly be admitted by all that the safe point of cut-off must be referred not to any arbitrarily fixed grade, but rather to the probable minimum level of the ground water at the particular site under discussion. The previously accepted safe cut-off point of grade 5.0 is still, so far as we know, reliable, but it would seem that, with the tendency for ground-water levels to subside, any proposed change should be in the direction of lowering rather than raising this cut-off level.

I think Mr. Bryant probably misunderstood the import of my recommendation as to stopping piles in a hard stratum when further driving would bring the points into softer material. I will agree that it will always be necessary to penetrate the harder overlying crust sufficiently to develop some friction rather than to depend entirely upon the bearing value of the pile point, but there are large areas in parts of Boston and the surrounding territory in which the great depth of underlying soft clay is covered by a blanket of gravel or much stiffer clay of substantial thickness, and it seems clear to me that a pile which develops a satisfactory resistance after it has been driven for a few feet into this hard crust will safely carry a much greater load if stopped than it will if driven further and into the soft underlying clay, where it will have neither bearing value or friction support of much consequence.

L. B. Manley (*by letter*). — An excellent opportunity for observing the character of the ground of the Back Bay section of Boston has been afforded by the deep excavation for the Boylston Street Subway. The preliminary borings for this work have been of great aid in foretelling the general nature of the ground and in the main have indicated a stratification coinciding closely with that afterward exposed. The subway excavation has, however, given much information not disclosed by the borings, and a short description of the materials actually removed may be of value in this discussion.

As is well known, the land reclaimed from the Back Bay consists of sand and gravel filling resting on a bed of silt whose upper surface lies at about grade 0, Boston City base, or grade 100, Boston Transit Commission base. This layer of silt is continuous throughout the length of the subway, and attains

a thickness of about 17 ft. at Dartmouth Street, and over 20 ft. in the Fens. Between Exeter Street and Charlesgate East and between Clarendon Street and Charles Street, where it finally disappears, it averages about 8 ft. in thickness. Below the silt between Massachusetts Avenue and Hereford Street, and at Exeter Street, are pockets of peat from 2 to 4 ft. in thickness. Another extensive body of peat occurs between Arlington and Charles streets, where it attains a great depth. In this bed of peat just west of Church Street, the well-preserved stump of a pine or cedar tree was found at a depth of 30 ft. below the surface of the street, or about 15 ft. below mean low water of the sea. As this stump probably grew at an elevation of not less than 10 ft. above mean low water, its presence at this depth indicates a settlement of the surface of at least 25 ft.

Below the silt and peat is a stratum of sand and gravel which also extends throughout the length of the subway excavation except for a length of about 1 600 ft. between Exeter and Clarendon streets. This sand and gravel carries large quantities of water laden with sulphureted hydrogen, which has been offensive to passersby and injurious to the health of those working in it. This gas as it leaves the surface of the water is particularly destructive to metal, and copper floats in several of the temporary pump wells have been corroded through at the surface of the water in a few weeks' time by the action of this gas. It is supposed that this layer of gravel is the same as that which appears in the bed of the Charles River and affords an underground water course which tends to equalize the level of the ground water in the Back Bay. The sand stratum rests upon a deep body of blue clay about 100 ft. in thickness. A boring near Dartmouth Street indicates that below the blue clay is a layer of hard pan or bowlder clay 4 ft. in thickness above the rock.

Silt.

The silt, which was evidently deposited through quiet water, is composed of finely divided particles of sand and clay, colored with organic matter. It is impervious to water and when dry will stand with unsupported vertical banks about

10 ft. high. It is compressible and shrinks and cracks badly upon being dried out. This silt should not be confounded with the peat, which is apparently composed chiefly of the remains of salt-water grasses washed into pockets by the tide.

To determine the bearing quality of the silt, a test was made in Boylston Street opposite the tower of the Old South Church, by loading a 12-in. x 12-in. timber set vertically on the silt in a hole 8 ft. square, in which the ground water was allowed to rise about 2 ft. above the bottom. It was not possible to observe the initial settlement when the timber was placed on the silt, but no further settlement took place until the loading of 5 500 lbs. per square foot had been reached. The table below gives the result of the test in detail.

1913.

July 7, 3.20 P.M., total load on silt, 3 187 lbs., no settlement.
July 8, 8.40 A.M., total load on silt, 3 187 lbs., no settlement.
July 8, 8.40 A.M., total load on silt, 4 342 lbs., no settlement.
July 8, 3.45 P.M., total load on silt, 4 342 lbs., no settlement.
July 8, 3.45 P.M., total load on silt, 5 497 lbs., $\frac{3}{16}$ in. settlement.
July 9, 7.30 A.M., total load on silt, 5 497 lbs., $\frac{1}{2}$ in. settlement.
July 9, 7.30 A.M., total load on silt, 6 652 lbs., $\frac{1}{2}$ in. settlement.

The settlement beyond this point increased rapidly, reaching $5\frac{3}{8}$ in. on July 10, 1913, when the test was discontinued.

Sand and Gravel.

West of Exeter Street, the sand and gravel below the silt is gray in color, well washed and graded from a fine sand on the surface to a coarse gravel at the bottom. This sand and gravel layer is from 7 to 20 ft. in thickness, and at most places affords an excellent support for piles. East of Clarendon Street the sand is more yellow and somewhat finer than that encountered west of Exeter Street.

Clay.

The clay is generally blue in color, and is evidently of glacial origin. For its upper ten feet it has been found to be hard enough to require the use of a pick for its removal. This hard crust has not been cut through often by the subway excava-

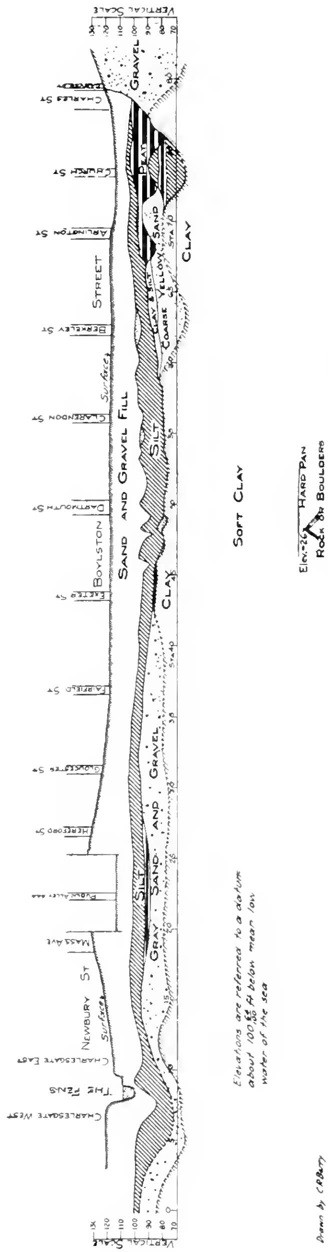

Fig. 1. Profile on Line of Boylston Street Subway.

tion but the borings and all observations indicate the clay to be soft and viscous throughout its lower portion.

The accompanying profile (Fig 1.) indicates graphically the location and amount of the materials encountered in the excavation for the Boylston Street Subway.

Subway Construction at the Old South Church.

The construction of that portion of the Copley Square Station of the Boylston Street Subway west of Dartmouth Street was made somewhat hazardous by the proximity of the lofty stone tower of the Old South Church, the foundations of which had, even before the coming of the subway, settled unequally in the soft silt and clay, causing the tower to lean noticeably toward the street.

This tower, which resembles in outline that of the Palazzo Vecchio in Florence, is a hollow stone shaft, 25 ft. x 28 ft. in outside dimensions, with walls from 2.5 to 4 ft. thick, and is connected on its north and east sides with the church building. At the belfry level, 120 ft. above the sidewalk, four corner turrets of brown sandstone are corbeled out and support the

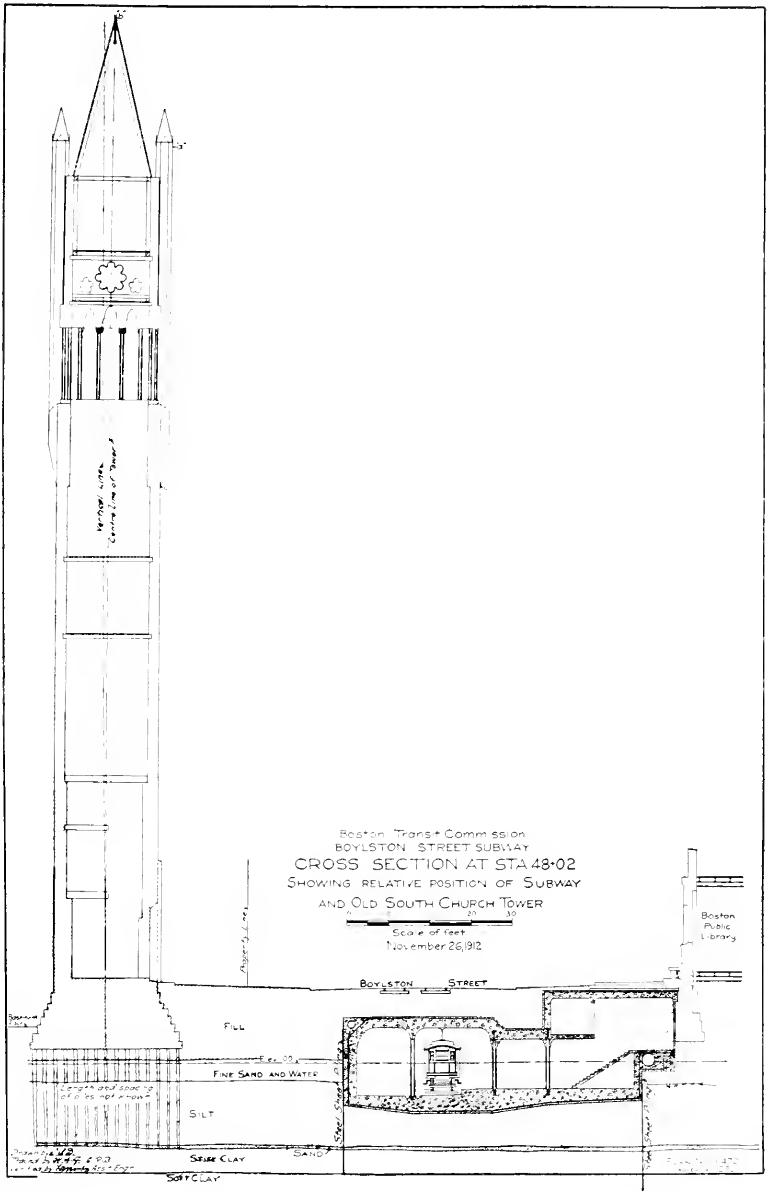
Boston Transit Commission
BOYLSTON STREET SUBWAY
CROSS SECTION AT STA 48+02
SHOWING RELATIVE POSITION OF SUBWAY
AND OLD SOUTH CHURCH TOWER
20
30
Scale of feet
November 26, 1912
Boston
Public
Library
BOYLSTON
STREET
Property Line
FILL
FINE SAND AND WATER
SILT
SAND
SOFT CLAY
Steel Sheet Piling

FIG. 2.

slate-covered wooden roof whose peak is 231.6 ft. above the sidewalk, 246.5 ft. above the bottom of the foundations and 263 ft. above the bottom of the subway excavation. The foundations are of granite, stepped out to 37 ft. x $42\frac{1}{2}$ ft. They are laid in lime mortar, as is the remainder of the stonework, and rest directly on spruce piles cut off at 3.5 ft. above mean low water. (Fig. 2.)

The records show that shortly after the completion of the tower in 1875, a distinct inclination was observed which gradually increased until, at the time subway work was begun, the tower leaned 2.5 ft. toward Boylston Street and 1.4 ft. toward Exeter Street, the resultant inclination being about 3 ft. toward its southwest corner or in the direction of the subway location. This movement of the peak of the tower corresponds quite closely with the inequalities of grade in the stone water table extending around the base of the tower and along the church vestry and parsonage toward the west, and indicates an unequal settlement of the tower considerably more than that of the neighboring buildings.

The total weight of the tower and its foundations is about 5 000 tons, which if uniformly distributed on its base would produce a load of 3.18 tons per sq. ft. The effect of the inclination of the tower is to shift the center of loading on the base toward its lowest corner, and this inclination, combined with a wind pressure from the northeast of 30 lbs. per sq. ft., has been computed to give a maximum intensity of loading under the southwest corner of over 5 tons per sq. ft. The number and length of the supporting piles are not known, but if, as supposed, these piles are spaced 2.5 ft. on centers, this maximum loading would correspond to a load of 32.5 tons per pile.

The character of the soil below the foundations of the tower is shown by the borings to be silt and clay for a depth of 115 ft. The filled material extends from 20 to 22 ft. below the sidewalk, or about $6\frac{1}{2}$ ft. below the tops of the piles. Below this gravel fill is 16 ft. of black silt resting on pockets of sand and gravel, and below the sand is 102 ft. of clay, hard on its surface but soft as putty for the remainder of its depth. Below the clay is a layer of about 4 ft. of hard pan, resting on bowlders or rock.

The great depth of silt and clay has caused a general subsidence of the adjacent territory, the results of which are everywhere apparent. Across Boylston Street the northwest corner of the Boston Public Library has settled about 10 in., and the curb between Clarendon and Fairfield streets has undergone a nearly uniform settlement of from 3 to 4 in. since it was reset in 1904. In Dartmouth Street, where the depth of the silt layer is greatest. the curb at the southwest corner of Huntington Avenue has settled .46 ft. in nine years, and at Marlborough Street it has settled 1.54 ft. in thirty-nine years, and the 6-ft. brick sewer in this street at Boylston Street was found to be 2 ft. lower than the grade at which it was set in 1870. Without multiplying instances, it appears that the general subsidence of the ground in the vicinity of Copley Square has been progressing at the rate of nearly 5 in. in ten years, and this subsidence may well have had its effect on the settlement and inclination of the tower of the Old South Church.

The cross-section of the Boylston Street Subway directly opposite the tower consists of a two-track subway with a 20-ft. platform and a lobby for entrance stairways and ticket offices 30 ft. x 55 ft. on the southerly side of the street. The width of the structure is about 80 ft. at this point. West of the lobby the two tracks and platform with side walls occupy a space 50 ft. wide. East of the tower the structure is widened by the addition of the north platform to 70 ft., the roof of which is supported by three interior rows of columns. The whole station is constructed of reinforced concrete and rests on a heavy invert designed to insure a uniform bearing over its entire area. The bottom of the subway structure is 30 ft. below the surface, and as previously stated is 27 ft. from the foundations of the tower at its nearest point.

To encourage bidding on this section of the subway, the Transit Commission assumed the responsibility for the safety of the tower under certain conditions, and in the exercise of this responsibility its chief engineer, Mr. E. S. Davis, prescribed the methods of construction to be followed at this point, which methods have been skillfully and successfully carried out by the contractor.

For various reasons, the Transit Commission decided not to attempt the difficult engineering feat of underpinning the heavy tower of the Old South Church, but in place of such underpinning to take the greatest pains to prevent any movement of the earth which would tend to reduce the bearing power of the piles supporting the tower. The method of operation adopted was, in brief, to construct the station in short transverse slices between lines of steel sheet piling previously driven, each slice on account of the possible upward movement of the bottom of the trench being completed before the excavation for the next had reached a depth of more than 10 ft. To prevent any inward movement of the steel sheeting during the construction of slices, a self-sustaining backwall of reinforced concrete was first constructed in a narrow trench, the timbering being so arranged as to permit the completion of the backwall without the removal of any braces. After this backwall was completed, the remaining core of earth was removed and the entire section of the subway slice constructed in one operation. As an additional precaution, the ground between the steel sheeting and the tower was filled with large quantities of neat cement grout, with the object of solidifying the sand pockets, closing underground water courses and making the sheeting watertight. These precautions were taken for a length of about 200 ft. on each side of the tower.

Throughout this length, it was decided to rest the subway structure directly on the silt without foundations, on account of the possible effect on the tower of the vibrations resulting from pile driving and of the risk of lowering the level of the ground water consequent upon sinking foundations to the hard clay. To prevent any lateral movement of the soil below the subway, a line of steel cut-off sheeting was driven below the invert at Dartmouth Street, between the rows of sidewall sheeting, and the soil inside the cofferdam thus formed was grouted with cement both before and after the construction of the subway structure.

The first operation was the driving of the steel sheeting around both sides of the subway and the westerly side of the lobby in Dartmouth Street, in a trench about 12 ft. wide and

10 ft. deep. The sheeting used was of the arched web Lackawanna type, 35 ft. long and weighing 35 lbs. per sq. ft. This was driven to the top of the subway structure by means of a Union Iron Works No. 1 hammer, operated by compressed air, the bottom of the piling extending 15 ft. below the bottom of the subway into the clay.

Grouting operations were next begun through 2-in. pipes, spaced 10 ft. apart next to the sheeting, except that in front of the church tower they were 5 ft. apart, which were driven to the clay by aid of a water jet. Through the open ends of these pipes neat cement grout, under 90 lbs. pressure, was forced into the ground until it would take no more, the pipe was then drawn up four feet and the grouting was continued in successive operations until the surface was reached. The pressure of 90 lbs. per sq. in. proved so great as to lift the walks and even to start one of the interior columns of the church, and it was afterward reduced to 50 lbs. per sq. in. with satisfactory results.

After the grouting was completed, the slice construction was begun simultaneously at the east and west ends of the sheet piling. The first operation consisted of the construction of the self-sustaining backwall in narrow trenches next the steel sheeting. On the south side of the subway this backwall carried a 36-in. sewer and was 4 ft. thick; on the north side the backwall was about 12 in. thick and reinforced with steel rods laid horizontally. As each increment of this backwall was carried about 5 ft. ahead of its corresponding slice, it was supported against an inward movement by this amount of the earth core on its forward end and by the completed subway in the rear. As the earth between backwalls was being excavated, these walls were braced apart by a heavy trussed brace set at the top and forward ends to supplement the supporting power of the earth core. These supports were sufficient in most cases to sustain the backwall during the excavation of the core and the placing of the main subway structure, but opposite the church tower ordinary timber braces were added, as the excavation was carried down, for additional support.

After the excavation between the sidewalls was completed, the concrete mat was immediately placed and the floor and walls

waterproofed. Then the invert was constructed, the sidewalls and structural steel placed and the roof concreted and backfilled in the order named. This cycle of operations took about seven days for completion. As soon as the invert was concreted in slice number one, excavation for the backwalls of slice number two was begun, so that by the time the whole of the construction in slice number one was completed the backwalls for the next slice were finished and core excavation between them was begun.

The sheet piling and the grouting of the soil was begun in the early summer of 1913, and the work of subway construction was started at both ends of the sheet piling during the last of June. After a short time spent in getting the organization to run smoothly, rapid progress was made, each slice, involving from 740 to 1 100 cu. yds. of excavation and from 178 to 200 cu. yds. of concrete, being completed in about seven days. During twenty anxious weeks, during which time the tower was constantly under surveillance, the slices approached each other, and on Thanksgiving Day, a day of special significance to all concerned in the work, the closing slice was substantially completed.

In consequence of this work, the total settlement of the tower at its lowest point was about one-half an inch, and the increase of inclination at the belfry was slightly over one inch toward the street. During this time the use of the church was continued as usual, and no visible results of any magnitude are apparent in the building in consequence of the subway construction; in fact, on account of the solidification of the subsoil by means of the grouting, it is supposed that the tower is now more stable than ever before.

Author's Closure.

J. R. Worcester (*by letter*). — The writer wishes to express his high appreciation of the discussion that has been evoked by the paper. The views expressed have shed much light on the points where positive knowledge is lacking, and valuable evidence has been presented which will help to narrow the limits of uncertainty about our foundations.

There is still some difference of opinion as to the last three

of the recommendations in the paper, but the first two have received practically unanimous support. Of those not generally supported, No. 3, that referring to the maximum and minimum elevation of the ground-water level, has met with most serious opposition, and the general opinion seems to be that the grades taken in the paper are too high. In deference to these views, the writer is disposed to reduce the minimum level to *grade 6.00*, so as to reach a conservative figure for cutting piles which can be recommended by all, though he wishes to record the fact that, as yet, nobody appears to have found timber in Boston or vicinity showing evidence of decay on account of dryness lower than grade 8.00. The maximum figure for computing head the writer is ready to reduce to *grade 11.00*.

The opinions with regard to recommendation 4, as to safe bearing value of soils, are quite divergent. Mr. Main would advise much lower units, while Mr. Gow and Mr. Bryant would advise higher loads, at least on some of the soils. The writer is disposed to allow the recommendations to stand, as presenting a fair concensus of opinion. Mr. Fernald's instance of a pier in the vicinity of Cambridge St. and West Cedar St. which settled 0.6 ft. under a load of 3.3 tons per sq. ft. seems to the writer to be so exceptional that general practice should not be based upon it. It was undoubtedly a case where blue clay overlaid soft material, but it seems most probable that the clay was really filling deposited outside of the original shore line.

The writer's suggestion for a pile formula has been considered somewhat radical by some, but has been endorsed by others. One point made by Mr. Adams is of much importance in this connection. It is well known that in our soils the resistance of a pile to driving is greatly increased by a few hours' set, which permits the soil to become readjusted and to get a grip on the pile. If the penetration is measured after a rest, and a formula of the form of the *Engineering News* type used, a much greater capacity will be obtained than if the final penetration after continuous driving is that employed. The writer's understanding is that generally the latter figure is the one taken, and it was with this in mind that the suggestion was offered of increasing the coefficient from 2 to 3. It is now suggested that in

case the penetration be measured *after a rest*, the *Engineering News* formula be used as it is, that is, in the form,

$$\frac{2wh}{p+1};$$

but that if the penetration be measured at the end of driving, it be taken as

$$\frac{3wh}{p+1}.$$

Mr. Bryant's criticism of the formula depending upon surface friction, that it takes into consideration the length of pile above the supporting stratum, is well taken, and any such method of computing the capacity should limit the effective length to the part within the supporting medium. Data is lacking in the recorded tests to check the units suggested by Messrs. Bryant and Adams, but the values seem reasonable. The allowance for a negative reaction from a penetrated crust lying above a compressible material is new to the writer, but this, too, appears rational and conservative.

Several suggestions with regard to piles are worthy of passing comment. Mr. Main's statement that "any wood pile which is to depend largely upon point bearing for its value should be oak or southern pine" seems to the writer to be a little too sweeping. If it were limited to piles which must be driven through or into a hard gravel, it would be incontestable, but, in many cases, it may be allowable to drive spruce piles down to a hard material and then stop. Care must of course be exercised under these conditions not to overdrive, but, using a short drop, this is not necessarily difficult. Mr. Adams's rule to space piles not less than 3 ft. on centers is very seldom followed in building foundations in Boston. With the small piles and soft soils usually found, there is no difficulty in placing them $2\frac{1}{2}$ ft. on centers, and the resulting saving of about 30 per cent. of the area seems to be legitimate. The disagreement between Messrs. Gow and Bryant as to the necessity of using double rows for piles is perhaps not so irreconcilable as it might appear. Mr. Bryant evidently has in mind the necessity of so

bracing the walls and piers as to allow for any eccentricity of the loads, while Mr. Gow is considering cases where stability depends solely upon the support the walls and piers get from the piles. There is no doubt that piles are very frequently driven considerably out of place, or, at least, that their heads are considerably out of place after driving. If reliance is placed on single rows, the walls and columns must be so designed that a very liberal allowance should be made for error of position, and full consideration should be given to unbalanced lateral forces.

The question of the subsidence of certain areas of the district is a very interesting one; the fact seems to be well established by the testimony of Messrs. Gow, Hastings, Howe, Adams and Carter. Whether it is due to a compression of the clay or a flow is still not definitely settled, but the preponderence of opinion seems to be in favor of the compression theory. Mr. Gow's suggestion that vibrations may tend to bring the surplus water in the clay to the top, whence it may be absorbed, is an interesting possibility, which appears to the writer as entirely reasonable.

Professor Crosby's report upon the geological formation of the land where the new buildings of the Massachusetts Institute of Technology are being erected is extremely valuable, as it is characteristic of the general formation of much of the territory under consideration. It adds much to. the value of the discussion.

Vol. I OCTOBER, 1914 No. 8

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

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SEWAGE MEASUREMENT AND AUTOMATIC CONTROL OF STORM OVERFLOW AT PAWTUCKET, R. I.

By George A. Carpenter, Member Boston Society of Civil Engineers.

(Presented before the Sanitary Section, February 4, 1914.)

Sewer construction in Pawtucket, R. I., began in 1884 and in the section of the city tributary to the filter fields in 1890. In December, 1894, the treatment of the sewage of a portion of the city by intermittent filtration through sand was begun and at the close of that year there were 5.57 miles of sewers contributing sewage to these fields from 102 connections. This was at a time when the purification of sewage through beds of sand was in its infancy and the adoption of this method of treatment was based upon the work of the Lawrence Experiment Station and the results at South Framingham, Mass.

At the end of the first year of operation there were 7 miles of sewers delivering an average of 58 000 gallons of sewage per day from 181 connections. The report of the city engineer for that year states as follows: "More than one half of this amount (58 000 gallons per day) is made up of ground-water which, in spite of the underdrains that have been laid under some of the sewers, still finds its way into them and, having mingled with the sewage, has to be cared for at the filter fields." "Notwithstanding this large amount of ground-water the average

Note. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, by December 10, 1914, for publication in a subsequent number of the Journal.

strength of the sewage . . . is greater than that of the sewage treated at the filter fields at South Framingham."

The total area of the beds at first was 1.67 acres and this was increased from time to time until, when last used, the area amounted to 3.36 acres. When the filter fields were constructed there were no traveled highways and but one building, a bleach and dye works, within 800 feet of the beds. Now there are several large manufacturing establishments in the immediate vicinity and one just across the street from the settling tanks. Large numbers of the help from these establishments travel the adjacent streets and cross the beds themselves, on the dividing berms, in going to and from their work.

During the nineteen years this plant has been in operation various experiments and studies have been made with the contact beds, septic tanks and screening methods, which the speaker will not attempt to describe at this time. Suffice it to say that the strength and quantity of the sewage gradually increased, and that soon the sludge obtained from sedimentation, which was formerly treated on sludge beds, became so heavy that other methods had to be adopted for its disposal.

Little difficulty is encountered in winter in the treatment of *settled sewage* on sand beds, for these can be furrowed in such a way that an ice bridge will form a protecting covering. It is the disposal of the *sludge* that causes the greatest trouble at this season of the year. The mat which forms on the sludge beds can be easily removed in the summer season, after it has dried out, but in the wet, cold weather of winter it will not dry by the time it becomes necessary to use the beds again.

In 1903 a screening chamber was built, which proved very effective and rendered it possible to dispose of this sludge in the winter when it would have created a nuisance if turned on the sand beds as formerly. By means of wooden racks alone and a location of the inlet to the screening chamber about three feet below the surface, more than 1 000 lbs. of solids (measured on the basis of dry solids) were removed per million gallons of sewage screened.

This screen chamber was in active use during the winter seasons from 1903 to 1908 and after that date sewage was screened

throughout the whole year. Once each week the screenings were pumped from the screen chamber into carts and carried to pits, or trenches, dug in the sand beyond the limits of the beds.

During the last few years of the operation of the filter beds the strength of the sewage averaged about as follows: Parts per million of suspended solids, 500; albuminoid ammonia, 18; oxygen consumed, 165, and the area of the beds was insufficient to care for the sewage being received. It became a question of either enlarging the area of the beds or of connecting the sewers of this district with the Providence system. As this plant is located within about 800 feet of the Providence line, the building of about 1 200 feet of sewer by that city and about 1 400 feet by the City of Pawtucket, was sufficient to connect the two systems.

After negotiations had been conducted between the two cities and after legislative sanction had been obtained from the General Assembly, a contract was entered into whereby the City of Pawtucket was permitted to connect the sewers of this district with the Providence system. This contract was made for a term of five years with an option of five years additional and upon the following terms: Pawtucket is to pay annually to the City of Providence $5 525.00 as rental for the use of the trunk sewers leading from the city line to the disposal works at Fields Point. This rental is based upon the interest on the cost of that proportion of the total capacity of the main sewer which was assumed to be reserved to, and used by the City of Pawtucket. In addition to the above, payment must be made for the actual cost of the treatment of the sewage at Fields Point at a fixed price per million gallons. The price determined upon by the City of Providence, as the actual cost of its own sewage treatment at Fields Point was $16.00 per million gallons, and this was the figure inserted in the contract.

It is also made a part of the contract that the City of Pawtucket " shall install and maintain . . . such a liquid measuring meter or such other measuring apparatus as shall accurately measure in gallons the amount of all sewage coming and discharging from said Pawtucket sewer system to and into said Providence system, and as shall be satisfactory to the Commissioner of Public Works and City Engineer of said Providence,

and shall keep such measuring apparatus in good repair and condition to execute its purpose."

The sewers of the City of Pawtucket have been built upon the combined system, and this fact in connection with the smallness of the minimum flow and the wide range existing between minimum and maximum dry-weather flow, complicated the problem of the design of a measuring apparatus which would satisfy the conditions of the contract.

The minimum flow in this sewer may run down, during the night and on Sundays, to a rate of 75 000 gallons in twenty-four hours, while its maximum rate, exclusive of storm-water, will reach a million gallons per day and more.

The use of a Venturi meter for measuring this minimum flow meant a throat diameter of less than three inches, which was altogether too small an opening for unscreened sewage. Besides, the range of one to thirteen between minimum and maximum flow was too near the limit of the range of a Venturi meter to afford sufficient opportunity for increasing this ratio if found necessary. The necessity of keeping a sufficient head on the throat of the meter at all times and of providing some practical means of clearing, or flushing, the small openings around the throat of the meter, all counted against the adoption of this form of measuring device for this particular place.

Many studies of various schemes for measuring the sewage were made, which finally resulted in the adoption of a 90-degree V notch weir, with an automatic recording device which produces a continuous chart record of the rate of flow, a dial record of the total flow, and a visible indication of the rate of flow at the time of observation.

The only objection to the introduction of a weir in the line of flow was the accumulation of sludge deposits back of the weir. This was provided for by making an ample outlet to the weir chamber through a quick opening valve by which the contents of this chamber may be easily and rapidly discharged.

It is believed that any automatic sewer apparatus must have regular and intelligent inspection if it is to be relied upon to do the work assigned it. And while this method of flushing, or discharging the contents of the chamber back of the weir once in

twenty-four hours, might easily have been made automatic and inspection limited to once a week, it was known that a man would be employed to look after this and other apparatus that will be installed later, and that, for the present, such flushing could be done by hand. Therefore the present method of operation is to have this gate opened each morning, except Sunday, when the attendant is not present, and the chamber quickly and thoroughly cleaned by the flow of sewage.

In answer to the criticism that the amount of sewage thus passing the weir is not measured, it may be stated that it can be easily measured by ignoring the drop made on the chart when the level of the sewage in the float chamber is thus drawn down, or a constant quantity, equivalent to the contents of the chamber back of the weir can be added for every time the chamber is emptied, or it can be neglected altogether. The latter proposition is the most practical, as it really forms such a very small proportion of the total flow that it can be neglected without appreciable loss.

The control of the storm-water overflow was a subject which called for considerable thought. It being conceded that in times of storm, the sewage combined with the storm-water must be turned into the stream, and as there will be no difference at such times between the sewage flowing over the measuring weir and that which would overflow and go to the river, it was desirable to obtain a positive shut-off for the weir discharge.

The common type of float-operated valve was not adaptable to the conditions of this problem, as too great a head was required for its operation, and the time of closing and opening was too great. A long study was given to working out the details of a float-operated pilot-valve, which should open and close a hydraulic gate, but this was finally abandoned, as it was found impossible to use a float for the power to operate such a valve and also to obtain a sufficiently fine adjustment. As it was desired to operate the opening and closing mechanism upon less than a half-inch difference in water level, it was soon found that sufficient power could not be obtained from this depth of flotation.

While engaged in the study of this problem, the speaker, by accident, learned that the old form of Venturi register, stripped of

a number of its details and with the addition of a tripping device, would furnish just the thing he was looking for. He also learned that, as a more recent form of Venturi register was being substituted in exchange for the older form, these latter registers could be bought at a very low figure. After working out the details of a pilot-valve attachment and float-operated tripping device, it was finally constructed, using this instrument.

These instruments are all installed in a concrete measuring chamber. The house was constructed with the intention of eventually filling over all except the center portion if it should ever be found desirable to fill in the beds to the level of the street. If this is done the windows will be closed in and a flight of concrete steps will be constructed to give access to the door.

The dry weather flow is diverted from the two trunk sewers through 12-in. pipes which join in a common line 15 ins. in diameter and enter the measuring house. The sewage is first passed through a rack to collect such floating matter as may have a tendency to clog the orifice. It then enters an 18-in. elbow through a 12-in. orifice and passes out through an 18-in. hydraulic

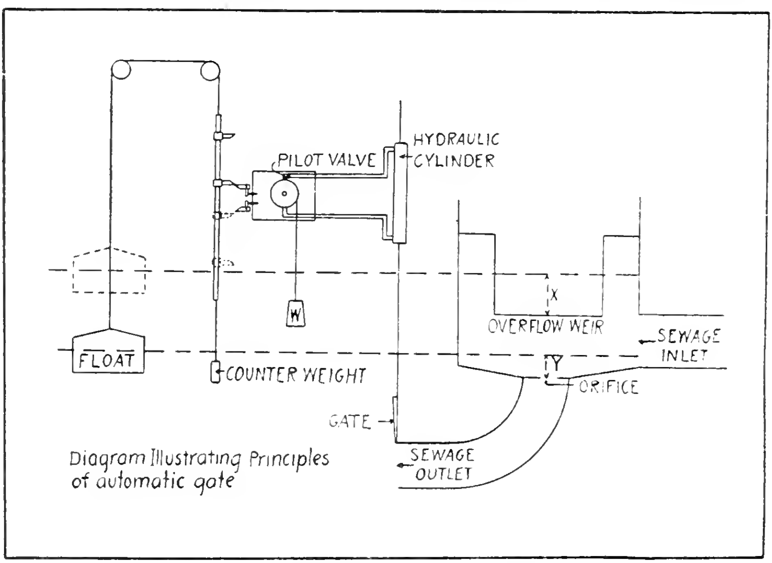

FIG. 1. DIAGRAM SHOWING HYDRAULIC CONTROL OF GATE.

gate to the weir chamber. In the orifice chamber there is a rectangular weir over which the sewage will flow upon the closing of the 18-in. gate. In the regulating chamber are located the float wells and floats by which the registering apparatus and the pilot-valve control of the hydraulic gate are operated, and in the measuring chamber a quick opening valve is used for discharging whatever sludge may collect back of the weir.

The method of hydraulic control of the storm-flow is illustrated by Fig. 1. This figure is diagrammatic only and was drawn merely to illustrate the principle of control. It is not drawn to scale and does not locate the different parts of the apparatus in their true relative positions. The sewage entering the orifice chamber reaches a predetermined depth, Y, over the orifice, when the float is brought into such a position that the lower tappet trips the pilot-valve, and water, under city pressure, enters the hydraulic cylinder and closes the gate.

The outlet being closed by the gate, the pipe and orifice immediately fill and sewage overtops the overflow weir to a depth, X. The float, following this rise, brings the tappets into the positions where the upper tappet is in position to again trip the pilot-valve when the storm-flow drops to a depth less than X. Any increase in the storm-flow will carry the sewage over the overflow weir to a greater depth than X, and the float will continue to rise. It is only upon the downward motion of the float, caused by a decreasing depth of flow, and at a predetermined depth over the weir, X, that the pilot-valve will again be in action and water will be admitted to the opposite side of the hydraulic cylinder and the gate opened. The sewage over the orifice immediately recedes to the depth, Y, or lower, and the instrument is in position to repeat the cycle of operation. The weights which furnish the power to operate the pilot-valve drop only $\frac{3}{16}$ of an inch with each movement of the valve plunger and are capable of opening and closing the hydraulic gate 100 times with one winding.

In Fig. 2 are shown the details of the tappets and operating mechanism of the pilot-valve. Back of the weights is the float chamber in which is located a large copper float connected to the operating rod shown on the right, upon which are fastened the

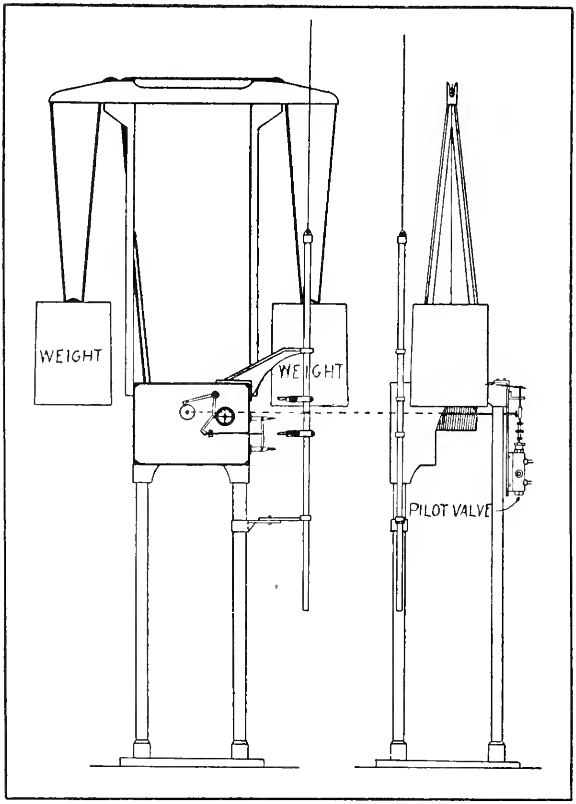

FIG. 2.

two tappets. As the float rises, this rod falls, and its tappets are brought into contact with the bell-crank arms on the instrument, and a slight movement of these arms trips the mechanism.

The recording apparatus, which has been referred to previously, is located over a float well and at the left of the float well of the control apparatus. The apparatus has now been in operation for more than a year and has given perfect satisfaction.

In connection with the study of storm-water flow in sewers it has been found very desirable to have some simple form of gage rod that can be suspended in the manholes and which will

record the maximum depth of flow reached during the storm. Various schemes have been tried, but the rod illustrated in Fig. 3 has given the most satisfactory results.

At the left of the picture the rod is shown complete, with its copper protector sliding in grooves in the wood. The view next to the one at the right shows the shape of this copper covering, which it has been found desirable to cover at the top as illustrated. The rod is pointed on the up-stream edge and the down-stream edge is cut out to receive the small glass bottles which are wired into this groove with their open tops 0.2 ft. apart. Foot marks on the rod, read in connection with marks two tenths of a foot apart, give the height of these bottles above the invert of the sewer. This rod is fastened in a manhole in such a manner as to be easily taken out for investigation and returned to the same location with reference to the water-line of the sewer.

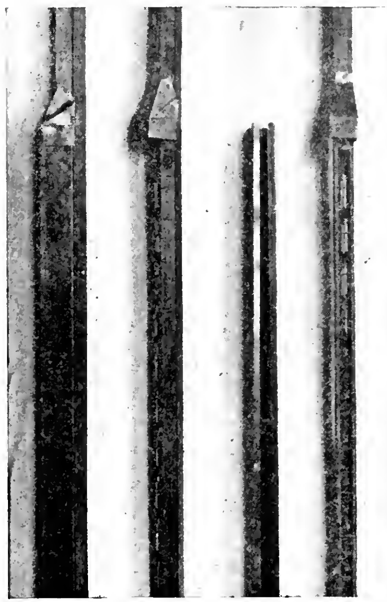

Fig. 3. Gage Rod.

It is not advisable to have the bottom of the rod dip into the dry-weather flow but it should go down only low enough to reach into the flow at the time of storms. The highest bottle filled with water will then record, within 0.20 ft., the flood wave of the storm. The protecting covering was found necessary to prevent water from splashing into bottles above the crest of the wave, thereby making the determination of the maximum flow uncertain.

Vol. I October, 1914 No. 8

BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

THE VENTURI METER FOR SEWAGE MEASUREMENT.

By CHARLES G. RICHARDSON, BUILDERS IRON FOUNDRY, PROVIDENCE, R. I.

(Presented before the Sanitary Section, February 4, 1914.)

THE Venturi meter has been manufactured in Providence and in London, England, for about twenty-two years. Although the original experiments were conducted on the measurement of clear water, Clemens Herschel, the inventor of the meter, realized that the principle could undoubtedly be employed for other liquids and for gases. This proved to be the fact, and the Venturi meter is now used extensively for many liquids other than water, such as brine, caustic soda, fuel oil, sugar solutions, compressed air, gas and steam. The first meter for the measurement of sewage was 48 ins. in size, and was installed at the Ward St. Pumping Station, Boston, Mass.

Venturi was born in 1746, in Reggio, Italy. After acquiring a good education he quickly built up a great reputation as an engineer and authority on hydraulic questions, and in one of his books on the movement of fluids he called attention to the peculiar law of nature now known by his name. This law, briefly stated, is: "When a fluid flows through a cone-shaped pipe there is a decrease in pressure, or sucking action, at the small end." Venturi saw no practical value of this property, it was simply a peculiar and incidental feature of his experiments in other directions.

NOTE. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, by December 10, 1914, for publication in a subsequent number of the JOURNAL.

In 1887 Clemens Herschel conducted a series of elaborate hydraulic experiments on various sizes of tubes composed of two conical portions joined at their small ends, thus forming a contraction at the middle, called the throat, and discovered that a remarkable relation exists between the inlet and throat pressures in such a tube and the rate of discharge through the throat. In fact he found that Bernouilli's formula, $V = \sqrt{2GH}$ was directly applicable with an exceedingly small range of coefficient, where V represents the throat velocity and H the difference in pressure between the inlet and the throat.

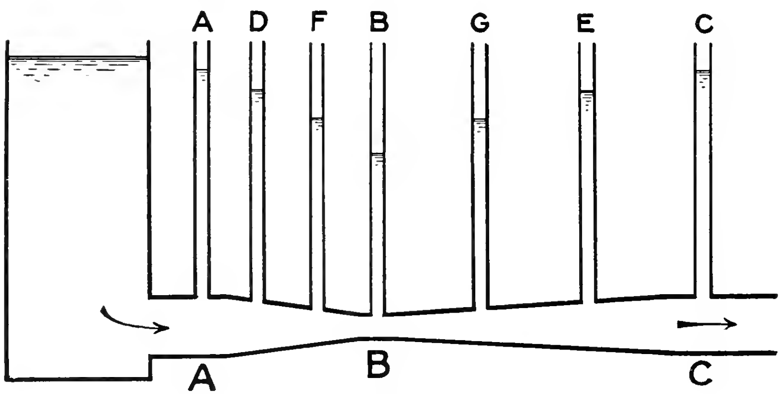


Fig. 1.

Fig. 1 illustrates the Venturi tube connected to a reservoir in which water is maintained at a constant elevation. A series of pipes, A, B, C, etc., are indicated, in which the water rises to the respective elevations shown when a flow occurs through the main tube. It will be noticed that there is a gradual decrease in pressure from the reservoir to the throat B, and a gradual regain in pressure from the throat B to the outlet C. This is due to the change of velocity in various sections of the tube. In standard meter tubes the drop at the throat may be as much as 10 lbs. at the maximum rate of flow for which the meter is designed, but the total friction loss between A and C will not exceed one pound per square inch.

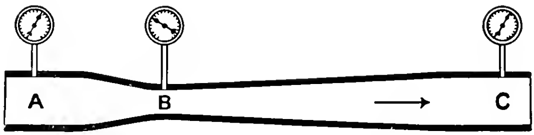
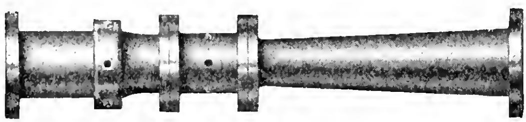
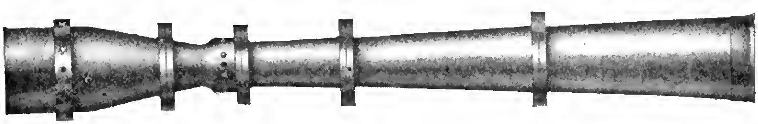


FIG. 2.

Fig. 2 shows the interior contour of a Venturi meter tube drawn to correct proportions. If pressure gages were inserted at the points A, B, and C, the hands would occupy the relative positions shown when water was flowing through the meter tube. That is, the readings at A and C would be practically the same, while there would be a distinct drop in pressure at B. The entire absence of any mechanism or interior parts should be noted, as the unobstructed passageway is of material importance in the measurement of sewage.



6″ VENTURI METER.



20″ VENTURI METER.

FIG. 3.

Fig. 3 illustrates commercial forms of the Venturi meter tube, the size referring to the diameter at inlet and outlet. At the inlet and throat is an annular chamber which communicates by numerous small vent holes with the interior of the tube so that the average pressure may be obtained at these points. Tapped holes are shown in each of these chambers for attaching small pressure pipes to connect with the indicating or recording instrument. The throat of each meter tube is lined with bronze,

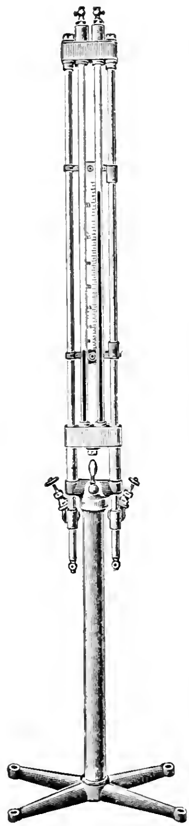


FIG. 4.
MANOMETER.

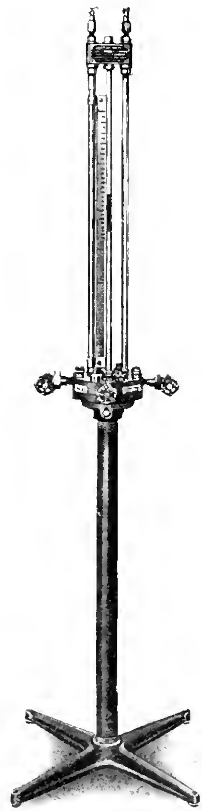


FIG. 5. IMPROVED
MANOMETER.

and, together with the adjacent portion, is accurately bored to the correct diameter and contour.

Many kinds of instruments have been devised for use with the Venturi meter tube. The simplest is the manometer shown in Fig. 4. Connections to the inlet and throat of the meter tube are made by two small pipes. The two glass tubes in the middle of the instrument are connected at the bottom by a passageway, forming a U-tube. The inlet pressure acts on the left-

hand and the throat pressure on the right-hand mercury column so that the difference in pressure can be observed by setting the scale with the zero line at the left-hand mercury level and taking the readings at the right-hand mercury level. The scale is graduated directly in gallons per minute or other units.

Another and later type of manometer is shown by Fig. 5. This instrument is constructed on the same principle as the barometer and has but a single glass tube in which the mercury column rises and falls in direct proportion to the difference in pressures. Hence it is unnecessary to set a scale to take a reading, a material advantage when making a test. The manometer is very light and readily portable.

The Type M indicator-register-recorder illustrated by Fig. 6 embodies the same principle as the manometer illustrated by Fig. 4. The glass tubes are, however, replaced by cast-iron wells about 3 ins. in diameter, connected at the bottom by a small pipe, forming the U-tube. Each well contains mercury and a float. When no flow occurs through the meter tube the floats stand at the same elevation. When flow occurs, the float in the right-hand well descends and the float in the left-hand well ascends, turning the indicator dial hand by rack and spur gearing. The lower, or indicator dial, is about 11 ins. in diameter, machine engraved and silver-plated. It shows directly the rate of flow through the meter tube at any moment. The upper dial carries a chart, 12 ins. in diameter, upon which is recorded continuously the rate of flow.

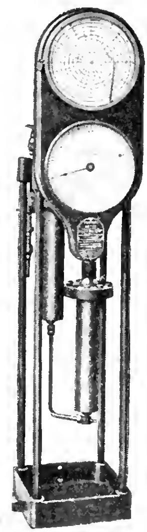


FIG. 6.

A special planimeter (Fig. 7) has been designed to integrate the charts from the Type M indicator-recorder. The charts are taken from the recorder and placed upon an aluminum disk furnished with the planimeter and the charted line traced in the ordinary manner. The planimeter reading is then multiplied by a constant depending upon the size of the meter, to obtain the total quantity.

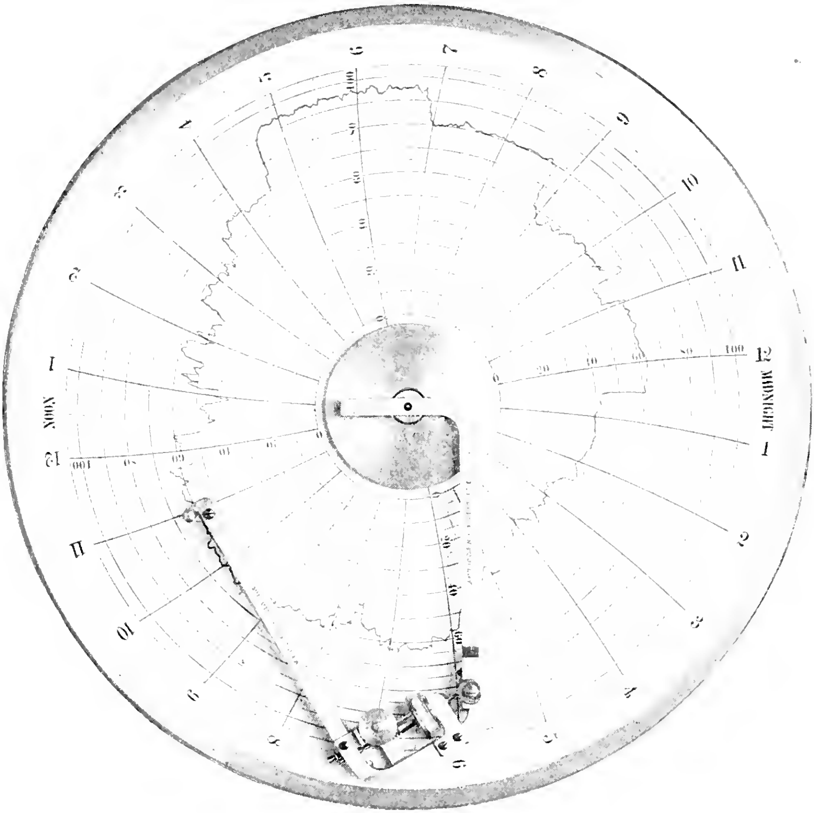


FIG. 7. VENTURI CHART INTEGRATOR.

In addition to indicating and recording dials the Type M register-indicator-recorder illustrated by Fig. 8 has a dial which gives the total number of gallons directly, in the same manner as an ordinary water meter. The interior mechanism is simple and does not require delicate adjustments.

Figure 9 shows a typical arrangement of Venturi meter for gravity or pump discharge main. It will be noticed that the meter tube is arranged as for measurement of water. For sewage a vault would be substituted around the inlet and throat

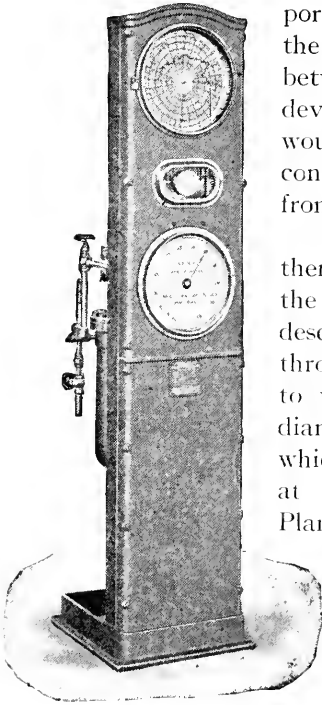


FIG. 8.

portions for the service boxes so that the chambers could be blown off, and between the tube and the registering device in the pressure pipe connections would be placed a small pair of reservoirs containing oil to prevent the sewage from entering the register.

In the measurement of sewage there is often not enough head to use the regular pressure-operated outfit just described. In this case the inlet and throat of the meter tube are connected to vertical float pipes about 8 ins. in diameter, as illustrated by Fig. 10, which was sketched from an installation at Far Rockaway, L. I., Disposal Plant. Here the meter tube was placed in the 10-in. discharge pipe from a duplex pump which led to a dosing trough. The two floats assume a difference in elevation due to the differential pressure between inlet and throat of the meter tube, and cords from the floats lead to a mechanism in

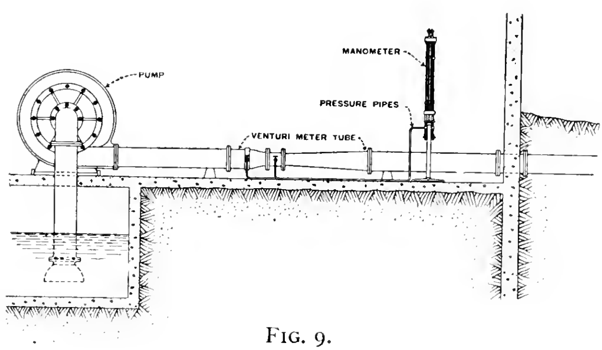


FIG. 9.

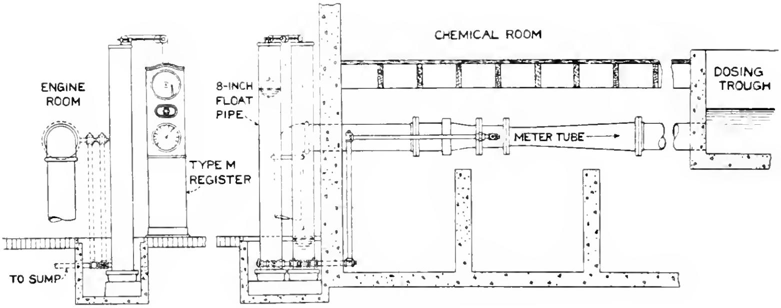


FIG. 10.

the back of the registering device which replaces the usual mercury wells. This mechanism is so arranged that the indicator dial hand of the register moves in exact proportion to the difference in level between the two floats. The charts from this meter are forwarded to the Department office in Long Island City, and they clearly indicate the rate of sewage pumped at different periods of the day and night as well as the time of starting and stopping of the pump. Thus they form a daily check upon the efficiency of the men who operate the station. This is especially significant in view of the fact that the sewage may be by-passed directly into the bay without treatment.

Baltimore has five 42-in. Venturi meters with 12-in. throats, each meter measuring the flow to a single hydrolytic tank. The outlet ends of the meter tubes are constructed of concrete. The largest venturi meter service for the measurement of sewage is at Boston. It is 60 ins. in size and is located at the Deer Island Pumping Station, where there are two 100 000 000-gal. pumping engines, only one of which discharges through the meter. It is estimated that during the year 40 per cent. of the total sewage flow passes through the Venturi. The 48-in. Venturi meter at the Ward Street Pumping Station of the Boston system receives about 95 per cent. of the total sewage.

Toronto has two 40-in. and four 56-in. Venturi meters with Type M indicator-register-recorders which are float-operated, the float pipes being arranged in clusters. The meters have proved especially valuable for regulating the dose of chlorine

and in setting the weirs which control the retention period in the sludge tanks.

Perhaps the most complete arrangement of the Venturi meter equipment for measuring sewage will be found at the new Fitchburg disposal plant. A 30-in. meter tube will be placed in a vault or pit and will be located in the main line to the Imhoff tanks. Around the meter tube will be placed a 20-in. by-pass line to be used in case of emergency. There will be a large manhole in the section of pipe immediately preceding the meter tube. A float-operated Type M register-indicator-recorder will be located on the second floor of the adjoining laboratory building. The 12-in. float pipes will be set in the laboratory and will be connected to the meter tube by 2-in. brass pipes. The piping is so designed that there will be a constant stream of water supplied through a small orifice near the top of these pipes, causing a slight flow through the pressure pipes to the meter tube, tending, automatically, to keep these pipes free from deposits. There will also be a water pressure connection which can be utilized to blow out the pressure pipes, wash out the float tubes or clean the annular chambers, should occasion require.

The smallest Venturi meter thus far installed for this kind of service is located at Providence, R. I., in a 10-in. line between a brewery and the Providence disposal plant. The city takes care of the factory waste wash water at a fixed rate per million gallons, as shown by the Venturi register.

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PAPERS AND DISCUSSIONS

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DESCRIPTIONS OF DEVICES FOR MEASURING THE FLOW OF SEWAGE.

By Messrs. Edward Wright, Jr., Frank A. Marston, Frank B. Sanborn, Edwin H. Rogers and Edwin J. Fort.

(Presented before the Sanitary Section, February 4, 1914.)

Edward Wright, Jr. — I hesitate to present a description of the comparatively simple automatic gage used by the Massachusetts State Board of Health after such good descriptions by our friends from Rhode Island of their more complicated and perhaps more accurate devices, but considering the fact that numerous requests are received for information relative to this gage I will offer a brief description of it.

The gage is used mainly for measuring sewage at disposal works where the sewage passes over a weir, although it has been used somewhat in the measurement of stream flow and in the measurement of the flow of trades wastes where it is possible to install weirs.

The gage (Fig. 1) consists of a copper float to which a rod and pencil are attached, and a cylindrical drum, which is caused to revolve by an ordinary clock mechanism. The float rod engages in two brackets which are provided with roller bearings. The paper upon which the diagram is indicated is wrapped around the drum and held in place by pins at the top and bottom and by rubber bands, and the elevation of the starting point

Note. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, by December 10, 1914, for publication in a subsequent number of the Journal.

in relation to the crest of the weir is obtained by means of a hook gage. The actual head on the weir is indicated.

The moving parts of the gage are constructed of brass, and while corrosion starts in very rapidly, the gage is so constructed that little or no difficulty ensues from this cause in its operation. The clock is so constructed as to run seven or eight days, and except when weather conditions interfere, the gage will run without attention for this length of time.

Owing to the great amount of moisture which at times rises from the sewage in the tanks where the gage has been used, it has been found that it was impossible to produce a pen-and-ink diagram, and, in fact, the moisture rising at certain sewage disposal works has been so great that the paper would be torn by the pencil, and to overcome this the very best quality of paper has been used.

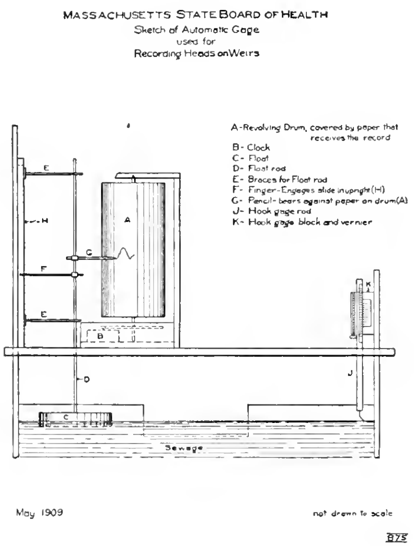

FIG. 1.

The most remarkable feature about this gage is that its cost exclusive of the weir is only about $25 or $30, which includes about $4 for the clock mechanism.

The gage is very sensitive and, in fact, the effect of matters rising with gas in the sewage in the measuring tanks under the float has frequently been indicated. The greatest cause for inaccuracy is due to the floating matters in the sewage, which displace the float and tend to clog the weir.

The diagram (Fig. 2) was obtained from a measuring tank to which sewage was conveyed in a system which admitted large quantities of ground water and probably some surface water, and the high heads indicated on the weir on the 22d are accounted

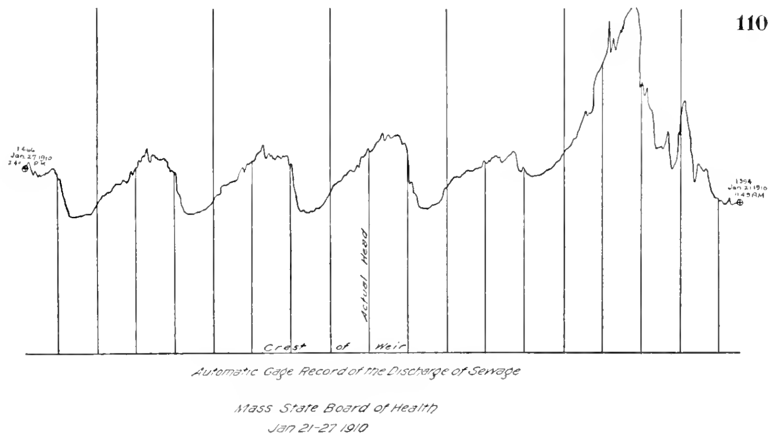

Fig. 2.

for by a comparatively heavy precipitation which occurred at a time when a large portion of the winter's snow was melting.

Frank A. Marston. — The flow of sewage at the sewage disposal works at Marlboro, Mass., is measured by means of a trapezoidal or Cippoletti weir, placed in a channel leading to the sedimentation tanks. The sewage enters the screen chamber through a long cast-iron pipe siphon, passes through a coarse bar screen, and along a channel 7 ft. wide, to the trapezoidal weir, as shown in Fig. 3. The crest of this weir is 2 ft. long and the sides have a batter of 1 in 4. The crest of the weir is set 18 in. above the floor of the channel. The weir itself is made up of 6 in. by $3\frac{1}{2}$ in. by $\frac{1}{2}$ in. steel angles bolted together and set in concrete. The inner edge or crest is planed to a true, sharp edge. The depth of flow over the weir is measured either directly by hook gage or rule, or by means of a recording gage of the Bristol type.

This gage, shown in Fig. 4, is operated by means of the pressure on a rubber diaphragm enclosed in a bronze box which is immersed in the sewage in the channel, and which is connected to the recording gage by a copper tube. The metal box containing the rubber diaphragm is installed so that when the

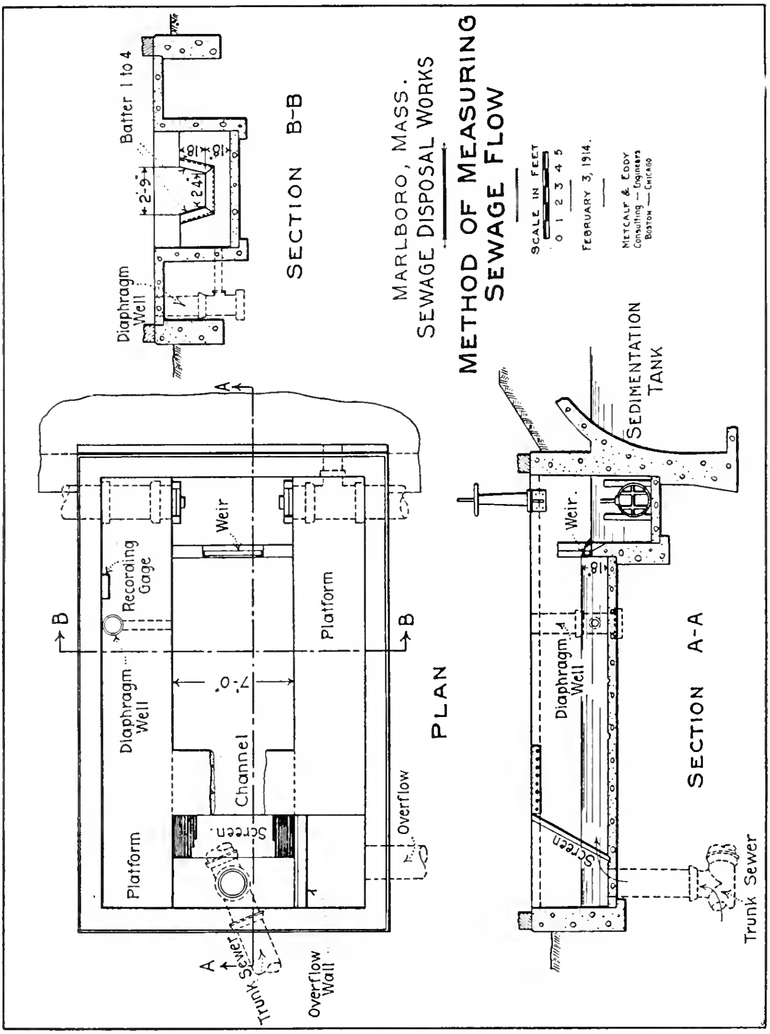

Fig. 3.

sewage is just level with the crest of the weir and there is no flow over the weir, the inside and outside of the copper tube is subject to atmospheric pressure only. As the level of the sewage rises there is a corresponding increase in pressure on the rubber dia-

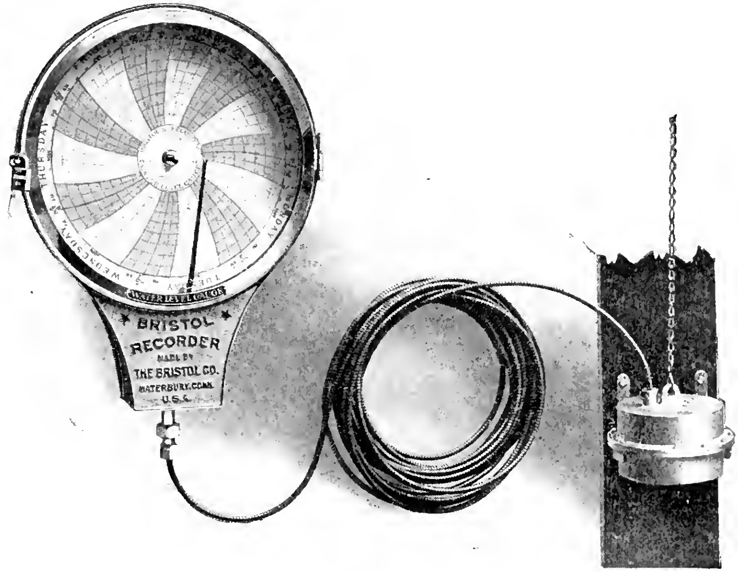

FIG. 4. BRISTOL GAGE.

phragm, which is transmitted through the air column in the copper tube to the metal pressure diaphragms in the gage. The movement of these sensitive diaphragms is multiplied and causes the pen arm to deflect over the surface of the paper chart. The chart revolves once in seven days, and is graduated in hours so that the record shows the depth of flow in feet over the weir continuously for each hour throughout the week.

The original plan provided a cast-iron pipe well, with connection to the channel a few feet above the weir, in which the diaphragm was suspended. The recording gage was fastened to the wall of the screen house.

After operating the plant for several months it was found that considerable sludge and scum collected in the diaphragm well and proved to be objectionable, although it may not have had any serious effect on the diaphragm or on the operation of the recording gage. Because of this collection of scum the diaphragm was removed from the well and was suspended in the channel itself, which arrangement has proved more satisfactory.

The average depth of flow is obtained from the chart by the use of a circular planimeter, and the quantity discharged by the trapezoidal weir is computed from the following formula:

$$Q = 3.366 \tfrac{2}{3} L\, h^{3/2}.$$

Q = quantity in cu. ft. per second.
L = length of crest of weir = 2 ft.
h = head on crest in feet.

There was considered, in the design of the plant, the possibility of using a Venturi meter or some other form of measuring apparatus which would obviate the necessity of constructing an open channel with its attendant difficulties due to the deposition

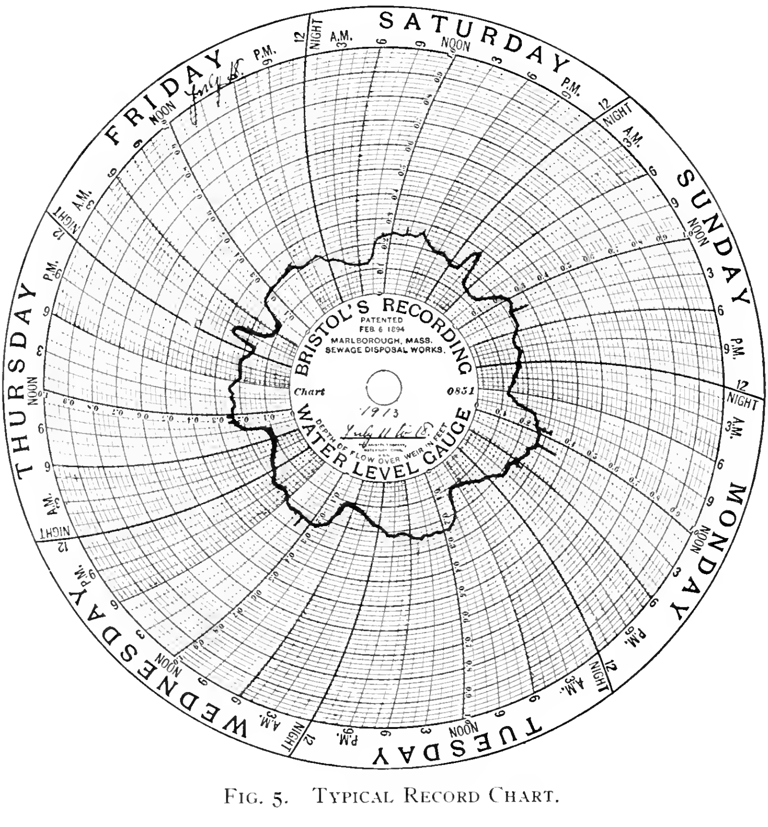

FIG. 5. TYPICAL RECORD CHART.

of solid matter, but it was felt that the city would not be justified in going to additional expense for this purpose.

The trapezoidal form of weir was chosen because of the great variation in flow to be measured. During dry weather single daily flows have been recorded as low as 150 000 gallons per twenty-four hours, and during the spring the flow has reached as high as 2 300 000 gals. per twenty-four hours for a single day.

Considerable trouble was experienced with this recording gage, especially at the beginning. The trouble did not seem to be due to any radical fault in the principle or design, but more particularly to the mechanical construction of this one instrument. The small copper tube leading from the diaphragm box to the recording instrument seemed to have a leak in it, allowing the air pressure to gradually escape, and while the record would appear correct for the first day or two, the pressure would gradually diminish so that the record would be noticeably in error before the end of the week. This trouble was apparently remedied and for some time the gage did excellent work and the charts obtained were of great value in the operation of the plant, but recently the trouble returned, putting the gage completely out of commission.

A typical record chart from this gage is shown in Fig. 5. This is a dry-weather flow and shows not only the variation in flow throughout the day, but also the number of times the screen was raked (shown by the radial lines crossing the flow line) and the time of pumping the sewage from a small low-level district (indicated by the hump in the flow line).

In studying the operation of the plant, it was found desirable to know the number of doses discharged by the automatic siphon from the dosing tank each day, and to obtain this information Mr. George A. Stacy, the superintendent, installed another Bristol gage in the dosing tank. This new gage has operated in a more satisfactory manner, perhaps partly due to the fact that the diaphragm is immersed in settled sewage. The charts obtained from this new gage have been satisfactory and of considerable value.

They show the rise and fall of the sewage level in the dosing tank, and are used not only as a check on the quantity of sewage,

but especially to determine the quantity applied to the various filter beds.

After about one year's service, a new rubber diaphragm was installed in the screen chamber gage. The old diaphragm appeared to have been attacked by something in the sewage, possibly sulphides, which partially rotted the rubber.

From the beginning of the operation of the recording gage in the screen chamber, the attendant has kept daily readings of the depth of flow over the weir, measured directly at a point a short distance above the weir. The attendant was instructed to take these measurements at approximately 4 o'clock each afternoon, and from the data thus obtained it has been possible

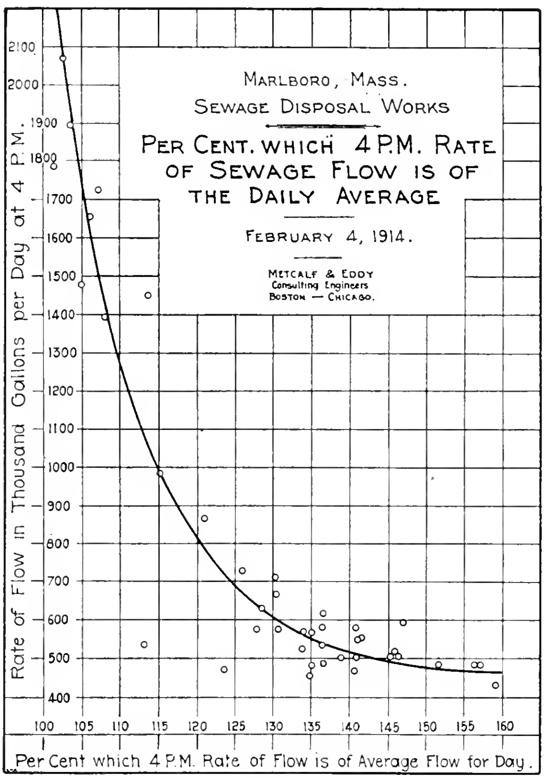

FIG. 6.

to check the readings of the recording gage and to fill in the records for the periods that the gage was out of commission.

A number of daily records were selected as being representative of the variations in flow, and from these a curve was plotted. Fig. 6, showing approximately the percentage which the 4 o'clock P.M. rate of flow is of the average for the entire day for varying rates of flow. By means of this curve the average daily flow was estimated, having as a basis a single measurement made at 4 o'clock in the afternoon. The results have been reasonably close and furnished a fair check on the working of the gate. The Marlboro sewerage system is largely on the separate plan, so that the variation in flow of sewage through the day is quite regular for certain average flows.

The experience with this type of recording gage at Marlboro, although somewhat adverse, is not of a sufficiently serious nature to prevent the gage being used in other places. The experience seems to point out, however, that it is very important that the gage be thoroughly tested at the factory before it is installed, and that every precaution be taken to make sure that the tube connecting the diaphragm with the recording gage be absolutely air tight. It is also of advantage to have the diaphragm immersed in as nearly clear water as possible, although the gage has operated successfully in what might be called thick sludge. Apparently septic sewage has some action on the rubber of the diaphragm, requiring its renewal perhaps once a year, but this can be easily done by a man of average mechanical ability and should not be a source of serious trouble. Where a slight leak does occur in the pressure tube or in some other part of the mechanism, it is exceedingly hard to locate and much harder to remedy. On the whole, the records obtained in Marlboro have been very valuable, and experience seems to justify this type of instrument as against a more expensive type, under the conditions at this particular plant.

Frank B. Sanborn. — Some time ago the writer had occasion to install a recording gage for measuring the flow of sewage of the city of Providence, and as some features of the installation were somewhat unusual, a description may be of interest.

The flow of sewage is about 24 million gallons per day,

about one tenth of which comes from a gravity system, the remainder being lifted 27 ft. at a point about 2 000 ft. from the disposal works.

The pumping plant consists of three Holly engines, each of which is connected with two centrifugal pumps, whose combined capacity is 43 million gallons per day.

The large size of these units necessitates a system of intermittent pumping during periods of small flow, as at night, or on Sunday, the sewage at such times being allowed to rise to a certain height in the large sewer leading to the pumping station, when the pumps are started, and operated until a certain low level is reached.

The discharge from the pumps, together with that from the gravity system, flows through an 88-in. conduit into a semicircular open mixing channel, 150 ft. long and 16 ft. wide. In this channel are placed 20 slate baffles, set 6 ft. apart on alternate sides, and projecting 6 ins. beyond the center line of the channel. From this channel the sewage flows directly to the four large sedimentation tanks.

Briefly, the conditions to be met were as follows:

The location of the weir was limited to the mixing channel, in which the baffles caused a very great agitation of the sewage.

The weir must be higher than the level of the sewage in the tanks, to be independent of variations in the method of operation.

It must be as low as possible, to avoid increasing the work of the pumps.

The opening of the weir must be sufficient to accommodate a flow of 120 million gallons per day.

The recording device must give an accurate record of the flow, without being so delicate as to be disturbed by momentary variations in height, due to currents in the mixing channel.

Owing to the sudden fluctuations caused by starting and stopping the pumps, the chart must be in terms of volume rather than of height, so that the total flow per day could be determined by the use of the planimeter.

Since the weir would not correspond to the requirements of any formula, the actual flow must be determined by experiment.

A location was chosen at the last baffle in the mixing channel, and a 10-ft. rectangular weir was placed at this point, having its

crest 9 ins. above the level of the sewage in the tanks, and 1 in. above the top of the baffle.

This greatly reduced the agitation in the mixing channel, but it was thought that the fall over the weir would give as good results as the former flow through the baffles.

By placing the weir at this location and height, no change was made in the conditions at the mouth of the 88-in. conduit leading from the pumps.

At a point 12 ft. up-stream a 3-in. pipe was built into the wall of the channel, 3 ins. lower than the crest of the weir. This pipe was carried into a large manhole, and another pipe was laid from the manhole to a 12-in. standpipe. The large amount of water in the manhole prevented the making of a wide line on the chart, due to momentary fluctuations in height.

The weir was then calibrated by experiment, the flow being measured in the various tanks of the plant, while observations were made of the height at the weir.

Points were thus obtained at rates varying from two million to 75 million gallons per day, and a curve was plotted to show the flow at any given height.

The recording instrument selected was the weir-gage made by the Hydro Manufacturing Company of Philadelphia. This instrument was intended to record height directly, and in order to get a record in terms of volume, the usual device was employed, of introducing, between the float and the recording pen, a cam or spiral which should be designed according to the formula for this weir. An 8-in. float was placed in the standpipe, and connected by a cord to a counter-weighted drum, having a diameter of 5 ins.

On one end of this drum was fastened a sheet-iron disk, 30 ins. in diameter, and on the surface of this disk, raised on blocks ½ in. high, was placed a brass track, whose curve was such that the distance from the center increased one tenth of an inch for each million-gallon increase in the rate of flow.

On this track was made to travel a small wheel, whose axle was attached to the lower end of a vertical rod, on the upper end of which was fastened the pen-carriage of the recording device.

By this means a chart was obtained which could be reduced to gallons per day by the use of an ordinary planimeter.

After the device was in place it was repeatedly checked in amounts up to seven million gallons, by actual measurement in the sedimentation tanks.

EDWIN H. ROGERS. — The Engineering Department of the City of Newton, Mass., maintained sewer gaging apparatus at three of the connections of its sanitary sewer system with the Metropolitan trunk sewer near the Charles River for a period of about a year during 1902 and 1903. These gages were in the form of a weir, with apparatus to measure the depth of flow, consisting of a float and a connection therefrom which registered the rise and fall of the sewage on a perpendicular revolving drum operated by clockwork.

No reduction gear was used, the actual rise and fall being recorded. The drums revolved once a week, requiring the renewal of the record chart every seven days.

The weirs were located in manholes of the sanitary sewers, and as their crests were raised from one to two feet above the invert of the sewers, they proved more or less of an obstacle to the discharge of the solid matter in the sewage, retaining a considerable amount of sludge which had to be frequently removed.

Considerable difficulty was experienced in the maintenance of the clocks, principally on account of the dampness which rusted out the hair-springs in their escapements and also tended to promote the growth of mildew in the works in such quantities as to stop them within a month, even though they were entirely enclosed in brass boxes.

The results obtained were in the main satisfactory, owing principally to the care exercised to keep the apparatus in suitable working condition.

In 1906 to 1908 attempts were made by the department to record the flow in three of the main surface drains of its separate sewer system for the purpose of obtaining data relative to the run-off of storm water. In one drain a weir was constructed with automatic registering apparatus, but was a failure, owing to the sand and other wash from the streets interfering with the operation of the apparatus.

In another instance a float was installed in a chamber beside the drain and connected with the invert of the drain by an inverted siphon.

Owing to the amount of rise and fall of the flow it was necessary to use reduction apparatus between the float and the register chart.

This method of measuring the flow could not be considered a success, partly on account of the pipe connection between the drain and the chamber being clogged with sand and other materials, and partly from the difficulty of calibrating the chart for different depths of flow in the drain. The drain was laid on a 3 per cent. grade and the flow through it caused apparent fluctuations in the float chamber which vitiated the attempts to obtain accurate records.

The third installation consisted of a float in a 12-ft. by 6-ft. drain, connected by reduction gear with a clockwork recording dial. It was found advisable to use a boat-shaped float of 4-in. plank, some 18 ins. wide and 8 ft. long, hinged by a 10-ft. rod to the top of the drain, and which floated smoothly and did not collect rubbish. The clockwork was housed without the drain in the open air, thus avoiding difficulty in its maintenance.

This apparatus was in operation with fairly successful results for several months.

A self-registering rain gage was maintained in conjunction with these gagings of the drains.

The element of time being an important factor in the derivation of run-off data, it is important that the clocks in the apparatus be closely synchronized, a serious problem, owing to environment and climatic changes, unless a system of electric clocks is employed.

After a considerable sum of money had been expended, it was decided that the results obtained did not appear to justify the further expense of maintenance and operation and the gagings were discontinued.

EDWIN J. FORT (*by letter*). — Various methods have been employed for the measurement of the flow in sewers in Brooklyn, N. Y. Of these methods the most successful have been the use of the self-recording water stage register and the knife-edge weir.

The self-recording water stage register referred to may be used in all sizes of sewers for domestic flow or storm water run-off. In using this method the hydraulic gradient of the flow is obtained by observation and measurement, as is also the cross-sectional area of the sewer for the depth of flow observed. The value of *n*, in Kutter's formula, is determined mainly by the exercise of judgment on the part of an experienced observer, in the absence of experimental data. Kutter's formula for velocity is then applied and by this means the quantity of flow is obtained.

Weir measurements are used in exceptional cases, especially where the entire flow of a drainage area or district can be weired in the out-fall trunk sewer.

The gage and weir, the description of which follows, have been used in experimental work of this character in a number of drainage areas in this borough, and the results have been quite satisfactory.

Objection may be made that such an estimation of the value of *n* is liable to considerable error and a resulting error in the volume of run-off, but even if this were true (of course the greatest care should be taken to estimate the value of *n* as correctly as our available information permits), the same value is also used in designing sewers, so that any such error would be compensated in the final result.

Self-Recording Sewer Gages.

The equipment used to measure the flow in sewers from the run-off produced by rainfall, consists of two Frieze self-registering water stage registers, and one vertical drum sewer gage designed by this bureau. Vertical flood sticks or maximum depth of water gages are also used to determine the maximum flood wave for a given storm.

Fig. 7 shows diagrammatically: (A) A water stage register placed on a shelf in an indicated manhole; (B) a copper ribbon passing over the transmission gear of the register; (C) a lead counter-weight attached to one end of the ribbon to keep it in tension so that the motion of the float arm will be transmitted to the recording device; (D) an adjustable float arm to which the other end of the ribbon is attached; (E) a copper ball float;

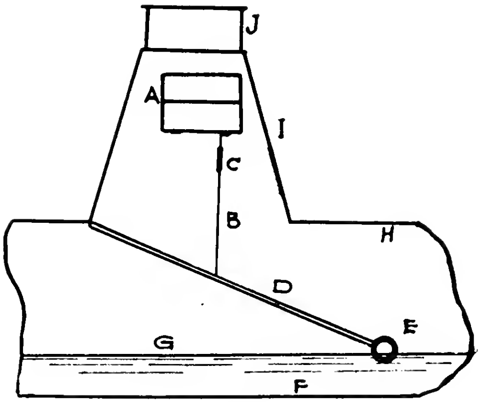

FIG. 7.

(F) represents the inner bottom of a 42-in. sewer; (G) the normal flow line; (H) the inner top of sewer; (I) the manhole and (J) the head.

The gages are calibrated by raising the float 0.5 ft. at a time, and noting the value of the movement on the recording device. In this way calibration curves and scales are drawn.

When installing a gage, the sewer in which it is to be placed is carefully measured, and a curve plotted showing the value of Q for all depths of flow. The gage is then placed in position, the ribbon attached to the float arm and counter-weight, a blank record placed on the drum and the pen inked and pressed down on the record ready for recording. The ball float is then placed 0.5 of a foot from the bottom of the sewer, the position of the pen and the elevation of the float ball being recorded on the blank record; the float ball is raised 0.5 of a foot more and the new position of the pen and elevation of the float recorded. This operation is repeated until the float ball has reached the inner top of the sewer. The elevations are then corrected for the depth of water required to float the ball. By comparing this record with the Q curve, a scale is made so that it will give the value of Q for any position of the pen on the record.

The height of a flood wave is shown on a well sanded vertical flood stick by the sand being washed off as high as the water

rises. This gives a very sharp line for the height of the wave and is of advantage in determining the slope.

Weir Gaging.

The use made of the weir is well illustrated by a concrete example; one of our problems was to determine the infiltration and the maximum and minimum flow of sewage for a large district, the population of which was about 177 671.

To obtain the desired information a weir was used, and the flow automatically gaged during the entire day and night for each day of the week.

The weir used was located in the out-fall sewer, or outlet flume, and belonged to the sharp-crested type, with end contractions suppressed. The crest length measured 25.84 ft. and the height 2.17 ft. The head on the crest when not affected by storm or snow water varied from .362 ft. at 4.30 A.M. on Fridays to .543 ft. at 3.05 P.M. on Tuesdays.

The device for recording the heads consisted of an automatic water stage register placed over a "basin" pit located just outside of the channel and about 16 ft. up-stream from the weir crest. The pit was connected with the flume by means of a 3-in. iron pipe 3 ft. long, laid on the floor and perpendicular to the side of the approaching channel. The zero for the register was determined by means of a hook gage and a Y level. The correction for slack motion of the register was determined by the hook gage to be ½ of one per cent.

Bazin's formula, $Q=MLD\sqrt{2GD}$, for suppressed weirs with velocity of approach, was used to plot the results of the investigation. It is suggested, however, that Hamilton Smith's formula, $Q=3.29\,LH^{3/2}$, for weirs of great lengths, may give more accurate results.

The total mean flow for twenty-four hours as indicated by the gage records was 18 123 000 gal.

The total amount of water supplied to the district gage according to information received from the Water Department was 17 767 000 gal.

Total amount of ground water (infiltration) per day, 356 000 gal.

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PAPERS AND DISCUSSIONS

DISCUSSION OF COST ACCOUNTING ON CONSTRUCTION WORK.

By D. M. Wood, C. O. Wellington, S. O. Martin, A. P. Porter, H. P. Eddy, M. L. Cooley, C. E. Patch and Leslie H. Allen.

Mr. D. M. Wood. — The subject of cost accounting is truly one with many complications. It is to be hoped that Mr. Allen's interesting and unusual paper will lead to a broad discussion and that many of the complications will then be eliminated through the general adoption of more uniform standards.

Cost keeping is not a new science, but its difficulties are constantly increasing, due to the gradual elimination of numerous small contractors on large jobs by fewer and larger contracting firms, with resultant diversity in their work, organization and equipment. It is essentially a subdivision of bookkeeping, the impersonal accounts being greatly subdivided. Unit cost keeping introduces the further detail of an exact determination of the quantities of work done corresponding to these various subdivisions.

Bookkeeping and cost keeping are so closely allied that no distinct dividing line can be drawn, and yet, as Mr. Allen states, there is a distinct difference in point of view. To make the relationship clear let us consider the case of a job of sufficient size to warrant including in the field organization an auditor, a purchasing agent, a material foreman, and a cost keeper. The

precise organization plan is not essential to the principles I wish to bring out. Let us assume that the functions of the auditor's division include straight bookkeeping and time keeping.

The timekeeper's duty is primarily to attend to the pay-roll. His first problem is to keep accurate accounts, in accordance with which disbursements can be made. He has, however, a second and even more difficult problem of allotting his labor costs to their proper sub-accounts. One set of records goes to the bookkeeper and the other to the cost keeper.

The material man likewise has a two-fold duty. He must first check the material received, by means of records furnished by the field purchasing agent. The largest material items are often purchased through the home purchasing department, but this does not confuse the situation, because they in turn send necessary records to the field agent, and the subsequent steps are the same. As a second problem the material man must allocate the material costs to their proper sub-accounts. He therefore reports to the bookkeeper, the purchasing agent and the cost clerk. The handling of teams usually comes under his jurisdiction.

All of this indicates the close team-play necessary between these men, who may in some organization plans be in entirely separate departments. It is not necessary to follow through a similar analysis of the work of the accountant or bookkeeper, except to call attention to the fact that numerous suspense accounts must be carried which are ultimately written off, the charges being carried to their proper cost items.

This brings us to the question of the proper code to use to simplify the work in field and office. Here I am inclined to differ from the author, favoring a numerical system more or less analagous in principle to that inaugurated by Dewey for library classifications. A system of this kind allows of ready subdivision to any desired refinement. This again shows the close relation between bookkeeping and cost keeping, since the book accounts can be confined to the broader items, while cost keeping goes into the small details. The original code should be confined to broad headings, working out a detail classification for the particular job.

Turning now to a different phase of the question, I would like to touch briefly upon a few details in which practice varies widely among construction companies. As pointed out in the original paper, it is desirable to keep entirely separate the structural or field costs and the overhead or intangible costs even in the final analysis. Carrying this idea still further, it seems desirable to segregate even in the final analysis some field accounts which in the past have sometimes been prorated to the general items of the work. To illustrate, — temporary construction (plant, cofferdams, railways, etc.), camp buildings, depreciation of construction equipment, etc., should be finally reported separately in many jobs instead of being prorated to the main items of the work. Still further carrying out this idea, the percentage relation of the above to the total structural cost is a useful unit; likewise, overhead charges such as field office expense, engineering, contractor's profit, insurance, etc., may be expressed as a percentage of the total cost. In particular cases they can also be expressed as some unit cost. It is also of value to know what percentage the labor costs bear to the total item and plant costs.

Leaving these generalities, I would like to raise what is perhaps the most important question of all, — that of definition of the unit. Here we find the greatest difference of opinion among engineers and the widest variations in practice. It seems to me that a proper discussion might eliminate much of the existing confusion. As a general illustration of this, let me ask what unit shall be used for the item of pumping in foundation work. The proper answer to this question probably depends entirely upon the character of the particular job, but even in any given case differences of opinion will be found. Assuming the case of a cofferdam for the foundation of a dam, shall the unit adopted be that of "per linear foot of cofferdam," or "per cubic yard of excavation." It is hard to say which would be better. The first might be justified on the theory that leakage probably varies with the length of the cofferdam. On the other hand, we may, for some particular reason, desire to include the cost of pumping under that of excavation or of yardage in the dam itself.

In computing the cost of a building per unit of volume, shall that volume be determined by the product of the ground area and the mean height of the roof? If so, shall the ground floor elevation be the line of differentiation between substructure and superstructure? If the ground floor elevation is taken as that separating line, what account shall be taken of any basement space below the ground line?

And so the cases of difficult definition can be multiplied without end. Many of them could be standardized after proper discussions among engineers. All of the foregoing only indicates the necessity of knowing the system used before relying upon published cost data.

This question of difficult definition serves also to indicate the responsibility which a cost-keeping clerk must assume in the field. While some arbitrary definition can be settled upon in advance at the home office, many times the field man must make instantaneous and intuitive decisions in order to properly allocate the labor and material costs. When, too, it is realized that the labor costs with all the complications in allotting it to the various subdivisions is usually a large percentage of the total cost, the bearing of the individual opinion of the various clerks upon the accuracy of the final unit costs reported is easily seen. To add to these difficulties there are usually so many details to be attended to almost simultaneously that the field men must necessarily make decisions without mature deliberation.

In the foregoing I have endeavored to bring out three general thoughts:

1. Bookkeeping and cost keeping are closely allied, the latter being a subdivision of the former. The use of a numerical code allows the easy expansion of bookkeeping into cost keeping.

2. There is need of a careful consideration of the unit of cost which is adopted in any given case in order that there may be no confusion as to what that cost includes or means. In using unit cost data it is necessary to know the system followed in obtaining it in order that its reliability may be known.

3. The accuracy of the results obtained by any system is mainly dependent not so much on the system itself as upon the men who are responsible for the allocation of the various expense

items to their proper accounts. Many times these men are none too responsible.

Whatever the system adopted it should be made simple to understand and should follow along logical lines of development.

MR. C. OLIVER WELLINGTON.* — Knowing that we have had considerable experience in designing and installing cost and accounting systems for a variety of industries, Mr. Allen sent us an advance copy of his paper, with the request that we look it over and prepare some comments that might be of interest at this meeting. The paper which he has just read was accordingly reviewed by Mr. Scovell and myself and some of our staff who are familiar with construction work, with the idea of commenting on the points that seemed most important from our experience.

Cost accounting is a division of bookkeeping, and the principles of double entry bookkeeping must certainly be followed in any reliable cost accounting practice, but just as the modern systems of bookkeeping are far in advance of the old-fashioned day book, journal and ledger, so Mr. Allen's methods are in advance of many cost systems for construction work. Probably the main reason for his success in working out the problems is because he has put the viewpoint of the field man, the engineer and the executive, ahead of that of the bookkeeper, and the results he has obtained are practical and can be used by the men in the field to give them the information by which they can reduce their costs; and that, in the final analysis, is what the contractor or any business man wants.

One member of our staff, while in the engineering department of an oil company, was engaged in the work of constructing a refinery. The head of the accounting department of the company decided what accounts must be kept on the construction work, and as these were useless for giving any information to the engineers, they found it necessary to collect cost data for themselves by operating an independent set of books while the job was in progress. This is an extreme case, but is typical of

* Of Clinton H. Scovell & Co.

the rather narrow ideas of the old-fashioned accountant to whom the figures are an end in themselves rather than merely a means to the end of reducing costs. This kind of narrow-mindedness is undoubtedly the cause for the prevalent opinion among engineers that accountants are all theorists, and that it is necessary to get as far as possible away from the bookkeeper's viewpoint in order to obtain data which is really valuable to the field man and engineer. The ideal is to make the accounting structure exactly parallel the actual work in the field, the same way that the cost accounting structure in a factory should follow the departments and operation. We have on our staff both accountants and engineers, and we find that the results which we obtain by combining their knowledge is far superior to those which could be obtained by either engineer or an accountant working alone.

Mr. Allen's comment on factory cost accounting leads me to think that he must have seen systems which were designed by men who were primarily auditors rather than cost accountants. The same ideas that he has applied to cost accounting for construction work are, we believe, the only ones which are practically correct, and the advantages to be gained from any cost system, that is, the reduction of costs, will be obtained through the superintendents and foremen to a greater degree than through the general manager, treasurer, or president of the company. The records, therefore, must deal primarily with the departmental operations, and yet if the whole system is well designed this information can be summarized to give the treasurer exactly what he needs to know about the operation of the business as a whole, and there should be no real conflict between the " Estimating Department " and the " Bookkeeping Department."

The use of a mnemonic code as compared with the Dewey decimal system, is an intensely practical matter. The mnemonic code has been used very successfully by some of our clients in recording tools, jigs and fixtures, as well as part numbers on more or less complicated machines. Mr. Martin M. Risberg, of our staff, who previously had charge of the cost accounting for the hydraulic construction work for the Mississippi River

Power Company at Keokuk, used the decimal system there and found it very satisfactory. The size of this work and the great detail into which construction costs were divided would probably have made the mnemonic code too cumbersone.

The exact information, as well as the comparisons made possible by sending weekly reports to the superintendents, showing the results of their own work as well as other jobs going on at the same time, is one of the most important features of any good cost system, as it is these men who will be able to use the figures to the best advantage to reduce costs on present and future work. There is another distinct advantage, that the superintendents will be able to check up the figures which they receive and correct any important errors in distribution. This brings up a matter which it seems to me is of vital importance, namely: Whether it is possible to keep cost records in Boston from field reports made up several hundred miles away. Other large construction companies have found that this is very difficult, and that although the system was apparently very reliable, the results were not satisfactory. The clerks in the main office keeping the cost records, very rarely see the construction job or know the peculiar difficulties which the field men must meet, and which have not existed on other similar jobs. Even if the cost clerks are very experienced, they are so far away from the actual work, that whatever they do must be largely mechanical.

What we believe is the best plan on construction work of large size is to put the cost accounting in the direct charge of a thoroughly experienced construction cost accountant, who is on the job continually, and has full control of the cost system. The chief cost man from the main office should, of course, visit all work occasionally, and regular reports will be sent to the main office showing in detail what is going on, but the distribution of labor and material must be carefully made on the job in order to give reliable costs, and the success or failure of a construction cost system depends upon the field men. That these field records, and in fact any cost records, must be "tied in" with the financial records in the main office is, I believe, too obvious to need any discussion.

The checking up of the work done, especially when the system

is first started, is a point Mr. Allen has brought out very forcibly, and I feel it adds emphasis to what I have just said, that a competent cost accountant on the job will be able to check up any errors in reports much more readily, and certainly much more quickly, than the clerks in the main office. Another advantage of having a good man in direct connection with each set of accounts is that little difficulties are bound to come up all the time which cannot be covered in standard instructions, and if the man on the job is not competent, the system is likely to fall down.

Mr. Allen's paper deals largely with labor records, but on a large construction job material and supplies are equally and sometimes more important, and they usually amount to more in dollars and cents. If the job is large, a stores system is essential in order to make a reliable distribution of material costs between one section of the work and another. Mr. Allen's statement that a record of all large purchases is made when the goods are ordered is very important, and is, of course, in line with modern ideas in regard to purchasing. It seems to me unnecessary for the bills when paid, to be sent out of the office to be receipted, and for the cost department to wait until they come back before entering them on their records. A properly designed voucher check will give the vendor all the required information in regard to the payment, and the bills can be permanently retained in the office.

The statement that once a month each job is brought up to date and compared with the bookkeeper's ledger, is obviously of great importance, as it is only by such a " tying-in " of the cost accounting with the general financial records that you may be sure that all charges have been distributed, and that the final results, as shown in the cost department, are in agreement with those in the general accounting department.

The indirect expenses, including the fixed charges such as interest, taxes, insurance, depreciation and repairs on the equipment used, must be carefully considered in comparing costs on jobs where valuable machinery is used, with those where much of the work is done by hand labor.

Mr. Allen's method of analyzing the estimate and arranging the cost accounts in accordance with this analysis is of great

importance. It often happens that engineers make up their estimates without sufficient thought as to whether the costs of the jobs can be kept in the same way, and then when the work is in progress, and they find that the cost records are not made up in the same way as the estimates, they place the blame altogether on the cost accountants. Coöperation between the estimating and the cost departments is very necessary if the final results are to be satisfactory.

It seems to me that the system which Mr. Allen has outlined is very well adapted for the work that his company is doing, especially as I understand that they have found it a practical success. In the final analysis, any cost system, whether crude or complicated, must be judged by its success or failure to give the management necessary information, and while I do not believe that any standard system can be designed which will fit all kinds of construction work or even different kinds of work and different jobs for any one company, yet I believe that the ideas which Mr. Allen has so well stated in his paper, if properly applied, will prove of material assistance to any engineer or contractor.

Dr. Selden O. Martin. — I came here to-night to hear Mr. Allen, and partly to hear my colleague, Professor Cole, who hoped and expected to be here. While I am not a cost accountant, nevertheless, at the Bureau of Business Research, at Harvard University, we have had considerable experience during the last three years in constructing and introducing a uniform system of accounts in about 26 states in the Union, for perhaps a more simple business, — that of shoes. And we have had some experience which made Mr. Allen's paper extremely interesting to me.

There are only one or two points to which I want to call your attention. He said the present system was not invented in a day, but has been a gradual development. He said it is easy to pay experts large fees to install a system, but it is not so easy to plug away, week after week, working it out. We had a simpler problem than his, and we tried to solve it by getting a committee together, composed of successful shoe men and of expert account-

ants, and they devised a system which we have not found to be defective in theory at all, yet gruelling experience has greatly improved it in practice, so that our experience with the relation of theory to practice, without speaking disparagingly of theory, has been the same as his.

Perhaps, after all, the most vital part of the paper is where it points out that on one job they ran $10,000 behind, and would never have picked it up, if it had not been for their system. That is the most vital point, because I think that it is all concentrated in that statement. Any good accounting system will tell a man where he is, but what he needs is a system that will tell him where he ought to be. He needs some standards to aim for. The author states that he has lowered the cost of his concrete, for example, by standards. In the same way we have worked out standards, and I think you cannot work them out except in a way like this. You must know where you should be, instead of having a post-mortem to find out that you were in error.

In regard to a mnemonic system, my experience has been that it is decidedly a better one to use than the numeral and decimal system, when the number of articles to be separately designated is not too great. For tools, for example, it has been possible to use a mnemonic system for several thousand. We can use mnemonic symbols for shoes up to several thousand variations and much better than with numerals. In fact, the mnemonic system, if correctly constructed, can usually be learned inside of twenty-four hours by a man of average intelligence, and at least inside of a few days. Furthermore, an extended use of it can be logically determined. We are now working on a stock-keeping system, and we found out that the first thing we had to do in establishing a uniform stock system was to get a proper symbol. We found stock numbers everywhere without rhyme or reason. We found that they used four when they wanted to indicate size six, and so on, and we finally devised a mnemonic stock system, and it looks as if it would be practicable. We tried it out on some who knew only the general principles of a mnemonic system, and they solved the symbol correctly nearly every time. It is also a great time-saver in itself.

There is one question I should like to ask Mr. Allen. He said that with a weekly payroll of $18,000, it required only two men to keep his cost accounting system. I wonder if he has any figures to show the percentage of expense now, and the percentage of expense to keep those records before the present system was introduced. I suppose it is a fraction of one per cent.

Mr. Allen. — In the old days we had nothing like the present volume of work, and I could not figure what it cost. At present the cost is about three-eighths of one per cent. of the value of the work done.

Dr. Martin. — I imagine it is just a fractional point of difference, but with almost any credible percentage, if it will save $10,000 on one job, there can be no question of its being warranted.

Mr. Arthur P. Porter. — The point has been brought out that the object of cost keeping is to check waste as the work goes along. I suppose it is also an object in cost keeping to make future estimates right. That is, the object of cost keeping is not only as applied to the job in hand, but to future jobs. Assuming that a contractor could know in advance accurately what each item was to cost, including its fair proportion of general expense, interest on equipment, etc., I would like to ask Mr. Allen if a contractor would make his bid directly on these costs or if there are considerations which would cause him to distribute his estimate otherwise. That is, if he could know about what concrete would cost him, would he choose to make his concrete low and his excavation higher than the work cost, or not?

Mr. H. P. Eddy. — I have been very much interested in this subject in rather an unscientific way for many years. Some fifteen years ago I undertook a fragmentary system of accounts in the city of Worcester, and one of the results, which I think possibly I may have described in these rooms before, but which I take the liberty of repeating in case you have not heard it,

was in finding out why it was costing us a great deal more to lay concrete in building a sewer than it should. We had figured out the quantity of concrete required and our cost accounts came in from week to week at about nine or ten dollars a cubic yard, whereas we had estimated seven and a half or eight dollars a yard. I went out and looked over the work, and it seemed to me that the men were working unusually well. It took me some time to find where the trouble was. The trench was cut out about the right size. I had looked out for that. Naturally the forms were placed at the right elevation, and the center had to be right, otherwise the vertical height of our sewer would have been wrong. The whole trouble was in placing the outside jacket forms to hold the concrete. The foreman, being of a generous disposition, had not taken much pains in placing these forms and had made the thickness of the concrete considerably more at the crown than was necessary. The sewer masonry was not of uniform thickness but was thicker at the haunches than at the crown. He therefore put in more of concrete than was actually called for by the design. Standing on the surface of the street and looking down at the work one would never have detected it. The foreman does not usually go down into the trench, which was about twenty feet deep, and it was our unscientific system of costs which detected the trouble and enabled us to remedy it.

Mr. Allen has not told us much about his method of distributing the cost of plant, which was one of the problems I had to contend with. We owned our own plant and had under way at all times from three to twenty construction jobs. The question was how to charge for plant. When a hoisting engine was sent out it might be on the job three months and used perhaps three weeks. The system we adopted was to charge the time of the machines just as we would the time of a man. If the machine left the yard the first day of January and returned the first day of March it was charged so many working days at so much per day, whether it was used or not, — and if the foreman neglected to send in the machine it was charged as so much unnecessary expense, but it was credited to the shop account which carried the machine. That charge was enough

to maintain the machine in good order, and a surplus which was credited to the whole shop account, so that at the end of the year the shop account was supposed to have cost the city nothing. As a matter of fact, when we were doing $250,000 work in the course of a year, we would balance up within $500.

The most difficult thing was the handling of small tools, like shovels, picks, drills, and water pails, which were sent on to the jobs, some of which were so small that if charged with the whole expense of the tools sent out in the first place, it would be an unfair distribution. The result of our studies was to charge a certain amount per man per day, which in those days was about five cents for small tools. The sharpening was charged extra, according to the amount done. I think that since then the "high cost of living" has required an increase from five cents to six cents per man. It would be interesting if Mr. Allen would tell us how he has met similar difficulties.

MR. M. L. COOLEY * (*by letter*). — I have read with considerable interest the paper on Cost Accounting on Construction Work. It seems to me that not sufficient stress is laid upon the very important factor of proof of costs to be obtained by controlling or checking them in total by means of the general financial accounts. This subject comes up so often in our work and is of such vital importance that in any discussion of costs we invariably look for method of proof.

It is true that cost accounting is in the nature of engineering work and that financial accounting is work for the bookkeeper, but there must somewhere be a connecting link between the two, otherwise the detail costs may contain many errors which will never be detected, and on the other hand, if they are subject to proof by controlling accounts in the financial records, it would be impossible for any material error to occur without being disclosed. In other words, the elements of construction costs being as in practically all costs, material, labor and overhead expense, the cost system which is subject to proof will have as its controlling elements a method by which the financial records will show

* Of Cooley & Marvin Co., Public Accountants.

that the total payroll for the month has been credited out of payroll account and charged to the cost of construction jobs; that all materials disbursed during the month have been credited to material accounts and charged to the cost of construction jobs; and that all overhead expense of every nature has been distributed in proportionate amounts to the various jobs worked on during the month.

This involves the use of accounts with construction jobs in process and completed, and while this general plan is no doubt entirely familiar to the author, in my reading of the paper I felt that it was not sufficiently emphasized, as, in my experience, there are still very many companies who do not realize the value of subjecting their detail costs to this method of control and proof.

Mr. C. E. Patch (*by letter*). — In the main, I agree with the author as to the need for cost accounting and the methods used in obtaining and using data, and I am sending a few notes giving impressions of the paper and some of the criticisms offered at the meeting, and other criticisms which my experience leads me to believe may be offered by some.

The stage of questioning the value of cost keeping seems to have been passed, and now the question is, "HOW?" There are still a large number of men who are not convinced of the value of cost accounting. Such might raise some questions in regard to the three purposes of a cost-accounting system as stated by the author in the last paragraph of page 135.

For instance, one might ask, in connection with the first reason: "When you have your cost data, with what standards do you compare them in order to determine whether they represent economy?

In connection with the second, one might raise the question: "When your cost data and estimates are at variance how do you determine which is standard?"

On the third, "Are all non-standard conditions eliminated from cost data before they are used to build up a new estimate?"

And on all three there are many who, like some of your society, might ask, "What does it cost?" and, "Does it pay?"

An up-to-date cost system, giving live cost analyses rather than "post-mortem" ones, is, to me, like the daily baseball score and standing records of our papers, in stimulating interest in the jobs. Before the players have reached their hotels after a day's contest, the score of the team, the efficiency of each individual player, and the standing of the local club, compared with the other clubs of the league, are tabulated and published. All this stimulates local enthusiasm and gives the manager a line on the weak points in his team. So your cost system, even though it may not be perfect, stimulates interest and focuses attention on weak spots.

In answer to the probable criticism of the first purpose of a cost accounting system which I gave, I believe that some form of operation study, by motion-picture, stop-watch, or time-record is necessary to set real standards and that even these are subject to human variations; but my experience as head of the Hull Estimating Division at the Boston Navy Yard during the past five years leads me to believe that your second purpose is invaluable in leading to standards for the first purpose.

When our estimating division was first formed, we were of course without other standards than had been built up in the minds and note-books of the individual members of the division. In case the cost of a job exceeded the estimate, an explanation was demanded, and it was usually assumed by those demanding the explanation that the costs must be correct, as they were actual data and the estimates only guess-work. I was not so sure of this, however, and before altering any estimating units involved, investigated the costs to ascertain the cause of the overrun, as well as checking the estimate to see if there were errors.

I became immediately convinced of two things: First, that the costs reported were very apt to be in error, due to lack of interest and care in charging time and material to the proper job order; and, second, that when due allowance was made for extra work not covered, due to the inexperience of estimators, and changes from the specifications estimated on, the cost was excessive.

It took considerable time to convince those who were re-

sponsible for the work that this was so, but eventually the younger officers agreed that there was chance for big improvement in performances as well as in estimating. A planning department was accordingly established, which undertook to so arrange the operations as to have the work performed logically, and to attempt a more accurate charging of time to proper job orders. An attempt was also made to record performances in order to obtain unit costs per operation, but after a partial success, so far as shop operations were concerned, this had to be abandoned, due to official differences of opinion as to their value. All who have known the history of the attempt admit that costs have been very largely reduced, and those in sympathy are enthusiastically in favor of planning and cost accounting being developed and extended. Comparison of similar jobs before and after comparative analysis of estimates and costs and the institution of planning, indicate a decrease of from 35 per cent. to 50 per cent. in labor cost and some 10 per cent. in material cost.

I have mentioned the foregoing to show that even though estimates and cost figures may not be perfect, comparative analysis of the two by operations will bring good results, tending to reduce costs and to give more reliable units for future estimating.

It has been stated that cost accounting should be a subdivision of the bookkeeping division rather than of the estimating division. I am inclined to believe that the author has the better arrangement. Cost accounting demands the scientific, or mechanical mind, and a knowledge of operations, machines and products which most bookkeepers do not possess. Bookkeepers have been trained to balance accounts and give value to the last cent of the account, though it run well up in the thousands. The estimator is usually a man of the scientific or practical type, and he knows better than any one the form in which he wants his costs, the units which are of value, and the best methods of subdividing jobs in order to obtain these costs. The best men to carry out his wishes are men of like mind, who have seen the work and understand the units, and the value of significant figures. Such men can be taught the necessary bookkeeping far easier than the average bookkeeper can gain the

practical knowledge. It may be that a new generation of bookkeepers will arise, who will meet the situation, but they still should work in conjunction with the estimating division.

The author's use of the mnemonic code has also been assailed; the main argument being that a numerical system would be more easily connected with the bookkeeping and correspondence filing systems. This was probably based on the premise that the other point as to bookkeepers was accepted.

Under the direction of Assistant Naval Constructor Otterson, we have been developing a mnemonic system which is used not only for the basis of cost accounting, but for filing, and I believe that especially where the product is near standard, and the number of trades involved is small, the mnemonic code is a valuable aid in cost accounting.

I note that in the comparison, Fig. 19, the author quotes costs per unit. Would not these figures at times mislead the men on the job? For instance, in many instances he may know that one job has excavation work which is so simple that it will cost but one half what some other job under way is costing, and he so estimates. A superintendent on a job at Philadelphia may receive the comparison and see that a fellow on a new job in New Hampshire is beating his costs by half. If he is conscientious this may worry him. Why not send out a comparison of cost per unit, divided by estimate per unit, this estimate to be corrected if later knowledge should show it to have been low, so that the superintendents get their comparative efficiencies instead of comparative costs? The same holds for all items. Difference in design may account for much of the difference in cost, and the efficiency comparison would be more equitable.

I do not quite follow the author's statement on page 136, that the factory cost keeper fixes selling price and the contractor's cost keeper does the reverse. It strikes me that both fix selling price, only one fixes it for goods already made and the other for the next lot to be made: i. e., the next contract.

Having been raised in the shipbuilding business where a large part of our work involves curves and graphic representation, such curves are second nature, and I cannot see why they could not be useful in many ways in the author's system of keeping

up interest among superintendents and firemen. For instance, assume a large excavating job. You are to start April 1, and the excavation must be done by May 15. The total yardage is 2 000. You estimate that it will take one day to clear the ground of underbrush and that thereafter digging will be at a fairly constant rate. Then a line from April 2 to May 15 (working days only) will give the cubic yards total to any given date. As each day's record comes in it is added to the previous total and plotted. This graphic representation of just how the job stands may appeal to some of your men more than figures, and will take so little time that it is negligible.

A similar plot could be made of costs and graphically represent profit and loss to date. Concrete pouring, the quantity of material to floor heights, etc., could all easily be plotted and afford a graphic check.

Leslie H. Allen * (*by letter*). — It is interesting to note the difference of opinion expressed as to the relation of the cost accountant to the bookkeeper. It is a very vital matter to the construction engineer and a good deal was said regarding it. It is undoubtedly true, as Mr. Wood says, that in theory cost accounting is a subdivision of bookkeeping, and yet as a practical matter it is very desirable, for the reasons brought out by Mr. Patch, that they should be handled independently. The refinery accounts cited by Mr. Wellington are by no means an exceptional case, but illustrate a comparatively common occurrence. It is, however, most important that the cost records should " tie in " with the financial records, as pointed out by Mr. Wellington and Mr. Cooley. One of the causes of the unreliability of much of the published cost data and cost analysis is the neglect of this very necessary precaution. It is well said that this needs no discussion, but it needs a good deal more emphasis than it was given in the original paper. It is astonishing to find how many cost records are kept without any attempt to do this. I have found many contractors' cost accounts with a balance unaccounted for at the end, of from five to ten per cent.

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* Author's closure.

of the total cost of the work. This is usually entered as "miscellaneous," although it should have been analyzed at the time the expense was incurred and charged to the various items of the work. Such methods of accounting give a false idea of costs, invariably making them too low, and as no contractor would think of adding five per cent. to a bid for miscellaneous expense, the result is likely to be financial loss in future contracts based on these prices. I feel, however, that it would be a mistake to attempt to divide the bookkeeping accounts so as to correspond with the divisions of the cost accounts; this would only make the bookkeeping more complicated and not assist the cost accountant in any way.

I believe that no one who has ever worked with a proper mnemonic code would ever wish to go back to a numerical system. A mnemonic code properly worked out is both a reference number and a description of the work referred to. A numerical code can never be more than a reference number. It is especially interesting to note Dr. Martin's experience with the mnemonic code devised by him. As I understand it, this is used not by one company but by a whole trade with great success. It need not be any more cumbersome than a numerical code; it is learned more quickly and used a good deal more readily.

The question is raised by Mr. Wellington as to whether it is possible to keep cost records in Boston from field records made hundreds of miles away We have found this to be the best plan; to put clerks in the field whose only duty it is to report the actual operations performed and to have all the computation and the compiling of these records done in the office. If a timekeeper is in doubt in what division to report an unusual operation, he reports it under a new code symbol and gives a brief note as to what it is. In the Boston office we decide whether to combine it with some other item or to keep it as a separate cost, and so instruct the field office with regard to further work of the same character. If such decisions were made by accountants in the field they would probably deal with them in different ways and the costs would not be upon the same basis. Under office conditions, with office appliances, work can be done in a third the time that it would take in the field. By means of photographs,

reports from the general superintendent, and occasional visits to the work, we keep in close touch with operations, and the plans and estimates on file in the office tell us the character of the work being done and the standards of cost.

The definition of units is important, but on construction work presents little difficulty. In our company it is covered by standard printed instructions which follow in general the customary practice of engineers. The cost of a building per unit of volume can hardly be reckoned an example, as the contractor's cost data deals with the various items of work and material that make up this unit. Cofferdams are not usually reckoned by units, but if any is required it would seem that for cost keeping the cost per thousand feet board measure of the lumber, and the cost per cubic yard of the filling, puddling, etc., should be determined, and for final cost data a cost per square foot of up-stream face (including freeboard) would be a proper unit to keep. Pumping bears no proportional relation to the size of the cofferdam, being dependent upon the weather and the flow of the stream. The writer's practice is to keep the total cost but no unit cost on pumping.

The point is raised by Mr. Porter, Mr. Patch and Dr. Martin as to the use of the cost data as standards. When estimating future work we certainly use cost data obtained on previous work as far as it is applicable to the work in prospect, and there would be nothing gained by arbitrarily making some costs higher and some lower than they really should be, as suggested by Mr. Porter. We do find, however, that there are so many differences in conditions on successive jobs that no cost data can be fixed as an absolutely definite standard of exact cost of future work. We endeavor to correct for the variables (or "non-standard conditions") in making up new estimates. This has to be a matter of judgment. In compiling cost data on work in progress, the standard they are compared with is the estimate. If it so happens that these are at variance it is a matter of judgment as to which is standard. If a careful investigation of the work being done shows that the work is economical, and costs, though higher than the estimate, cannot be reduced, the estimate has to be corrected. More frequently it happens that if actual

costs are higher than the estimate, an investigation shows some inefficiency which is removed and the cost lowered, as in the case cited in the original paper, which, though not typical of all our jobs, was not the only one having a similar history.

The suggestion of Mr. Patch that in sending out the comparison sheet (Fig. 19) we give actual cost per unit divided by estimated cost per unit, is a novel one and might be valuable. It must be borne in mind, however, that we only pick out a few of the big items for this comparison which are more or less standard. We never include excavation costs in this sheet, as their fluctuation is so large.

I have not given much space to the accounting on material and supplies. It is true, as Mr. Wellington says, that these usually amount to a good deal more in money than the payrolls, but their distribution is a simple matter. Construction work is not like factory work, where several hundred tons of steel or other material may be bought and taken into stock and issued to various departments in small quantities; in construction work the material actually required for each part of the work is scheduled and bought and its distribution is known before the order is placed. When it arrives on the job it is used for its intended purpose. In the case of materials like bricks and cement, the quantities for each part are also known in advance and can be better distributed according to schedule than by the expensive method of paying a storekeeper to issue and check them. Waste is a comparatively small item on construction work and the permissible percentage on different materials is known at the time of ordering and allowed for. On the other hand, the fluctuations in labor costs are great, and need very careful watching; on them the profitableness of a contract usually depends and they are the most reliable indication of the efficiency and economy of the job. To judge whether a job is efficiently handled or whether a gang or a man is working economically, it is not sufficient to visit the job and watch the men at work. We all know the spurt put on when the boss or any one in "good clothes" visits the job. It is necessary to know what the work has *cost*, and to determine whether the job is improving or declining in efficiency we need to know whether the unit costs

are higher or lower than those of the preceding day or week. We have to compare these actual unit costs with those of the original estimate to see if we are making or losing money on each item. This will indicate the need for particular care in some items on which money is being lost in spite of their apparent efficiency.

One of the great difficulties of cost accounting on construction work lies in this constant change of work and change of men on the job. Men who work half a day digging a trench are then transferred to unloading steel or working hand pumps. Carpenters who are placing concrete forms one day in gangs of two or three may be the next week hanging doors or jointing in sash, singly. The job may start with ten men and in three weeks be employing a hundred, increased later to a hundred and fifty, and then drop to twenty, three weeks before the job closes. There is no continuity of operation which can be systematized, and as soon as a man has reached efficiency on one operation he is likely to be transferred to another piece of work entirely different. All work is done in the open air in varying temperatures and weather conditions, and for all these reasons *the fluctuations in daily and weekly costs are very great and need very careful watching.*

In accounting for plant, we use a similar method to that outlined by Mr. Eddy. A rental rate is determined for all items of large plant, — mixers, engines, pumps, motors, etc.,— which is calculated on the basis that by the time the machine is worn out the rentals will have provided a fund large enough to replace it, as well as paying for occasionally overhauling and repairing when needed; but on small tools and supplies the character of our work requires a different method of accounting. When a job is started the tools and supplies sent out are charged to it according to their value, and when the job is completed all tools and supplies returned, including any that may have been purchased locally, are taken into stock and credited. All incoming and outgoing tools are valued by the yard master, according to our standard valuations.

New articles are charged or credited at 100% of their value.

Articles in good condition are charged or credited at 75% of their value.

Articles in fair condition are charged or credited at 50% of their value.

Articles in poor condition are charged or credited at 25% of their value.

Worthless articles are charged or credited at 0% of their value.

It is a rule that there shall be at least 25% difference in the value of articles sent out and returned, and usually it is more than this. In this way the owner gets charged with a fair price for the use and loss of tools, etc., without having a lot of tools useless to him left on his hands at the close of a job. I have never worked out the value of tools on the man hour basis, as it is not applicable to our work where so many are carpenters and masons, but I should judge that on municipal work of the kind described by Mr. Eddy it would be a very simple and accurate method of accounting.

I have not said much about distribution of indirect expense, except that portion of it which is labor in the field. This, as I have stated on page 159, is distributed every week as a percentage of the payroll. It consists of the overhead cost of superintendence, including timekeepers and material clerks, water boy, etc. I distribute this cost every week in proportion to the labor cost of each item, except that at the beginning of a job, for the first few weeks of its life, the job overhead is very high in proportion to the payroll and the expense of same is mostly planning for the work ahead rather than supervising work being done. For this reason I do not distribute this cost until it comes down to a certain percentage of the total payroll (usually 8%) and then all costs are corrected by adding this item.

The other items of indirect expense, such as plant, fuel, insurance, bond, are usually figured by contractors as direct expense in their estimate, and during the progress of the job may be fairly considered as such, although in the final analysis and summary of the job costs they should be distributed. In the analysis we carry the cost of plant in lump sums, but in finally analyzing the cost of the work done the correct way is to dis-

tribute it according to its relation to the amount of work done. If you put a steam shovel on a job it is to save the hand labor of so many laborers, and if the rental, fuel and operation of a steam shovel cost $1 000, while 10 000 cubic yards of earth were taken out, it is obvious that ten cents per cubic yard is part of the cost of steam-shovel digging to be added to the labor cost of the men mucking around it. If 5 000 cubic yards of concrete were mixed and hoisted by a concrete mixer and hoist, and the labor cost of charging the mixer was $1 500, and the rental, fuel and supplies cost $2 500, the total cost of mixing and hoisting concrete is $4 000, equal to 80 cents per cubic yard. If no mixer had been used and the concrete mixed by hand, the labor cost might have been about $1.50 per cubic yard, or more.

It is not usual for contractors to charge home office expense and salaries to the job in hand. A contracting company carrying out eight different jobs may be likened to a holding corporation with eight subsidiary companies. The accountants of these companies do not include in their accounts any of the expense of the holding company, and similarly, each job of a contracting company should have a separate cost account and not bear any of the head office expense. In a factory, the position is different. There each department does a different operation, the whole combining to make a finished article, and the cost of this article cannot be accurately determined until the administrative expense of the factory corporation is added.

In conclusion, it remains for me to express my hearty thanks to those who have so kindly expressed their appreciation of my paper, and especially to those who have added so much to its interest by their discussion and criticisms. There are so many firms that are wrestling with the same problems that a further discussion of the subject seems very desirable with a view to getting some uniformity among contractors' cost accounts. We cannot expect to have accounting standardized for us like the uniform accounts required from the railroads by the Interstate Commerce Commission, but a lot could be done, as has been done by the Harvard Bureau of Business Research in the shoe retailing trade, or by the Sanitary Section of our society on sewerage data, and by the printing trade. If the society saw fit to appoint a

committee to draw up such a system with the necessary forms, such a work would be of benefit to engineers and contractors, and would reflect great credit upon the Society.

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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

THE BOSTON & ALBANY RAILROAD IMPROVEMENTS AT WORCESTER, MASS.

By Luis G. Morphy, Member Boston Society of Civil Engineers.

(Presented February 18, 1914.)

Historical.

On June 21, 1890, the General Court of Massachusetts approved the statute (C. 428), entitled, "An Act to Promote the Abolition of Grade Crossings." This was the first general law providing for the abolition of grade crossings which fixed the distribution of the expense by proportions between the parties interested.

The authorities of the City of Worcester, realizing the advantages and necessity of eliminating the grade crossings in that city, acted promptly, for on July 28, 1890, an order was passed by the Board of Aldermen and approved by the Mayor, authorizing the City Solicitor to petition the Superior Court for alterations in the crossings at Grafton Street, Green Street, Washington and Plymouth Street foot-ways, and the extension of Madison Street. Acting upon this petition, the Superior Court appointed a commission, consisting of Harvey N. Shepard, Joseph S. Ludlam and Fred Brooks. The first hearing was held in November, 1890, and a view was had of the premises. Favorable public interest and equally great opposition developed during the

Note. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before January 15, 1915, for publication in a subsequent number of the Journal.

hearings before this commission. In addition, questions of interpretation of the original Act were raised, and the city authorities passed the order requiring the commission to report to the Superior Court against any change under the original Act. The commission reported on Grafton Street only, and recommended that Grafton Street be depressed $13\frac{1}{2}$ ft. and the railroad tracks be raised 2 ft., leaving headroom of 13 ft. The Superior Court made no decree approving this report. At the same meeting, the city authorities passed an order that a commission, consisting of the City Engineer and two other expert engineers, be appointed by the mayor to study the subject. This commission consisted of Chas. A. Allen, city engineer, Augustus W. Lock, of North Adams, and John W. Ellis, of Woonsocket. Exhaustive studies of all possibilities were made, and the commission reported, in January, 1893, in favor of elevating the railroad and depressing the streets, also separating the thirty-nine then existing grade crossings into those which could be dealt with separately and those which constituted a single problem and should be considered together. This paper deals only with the latter group.

From time to time, during and after 1893, some of the crossings which could be dealt with separately were eliminated, but no further progress was made with the group constituting the single problem until 1899, when the mayor was authorized to appoint two competent and disinterested engineers, who, together with the city engineer, should study the general problem. This commission consisted of F. L. McClure, city engineer, Rudolph Hering, of New York, and Desmond FitzGerald, of Boston. They reported in favor of elevating the tracks, raising them 16 ft. at the Union Station.

On July 23, 1900, the Board of Aldermen authorized the City Solicitor to petition the Superior Court for the improvements in accordance with this report, and the commission appointed consisted of Jas. R. Dunbar, Henry P. Moulton and George F. Swain. Late in 1904, Mr. Moulton died, and early in 1905 James H. Flint was appointed. This commission made its report under date of June 18, 1907, and the Superior Court decreed that the work should be done accordingly.

Layout.

The grade crossing decree called for a general elevation of the railroad tracks and some depression of the streets. A new Union Station was to be built near the old one, but in the " V " between the Boston & Albany and the Boston & Maine R. R., or viaduct location. The approved plans showed track layout for the railroads, profiles, land takings, the Union Station and the types of bridge structures contemplated. The cost was proportioned according to the Massachusetts law, the different railroads sharing the 65 per cent., according to the location of different divisions of the work.

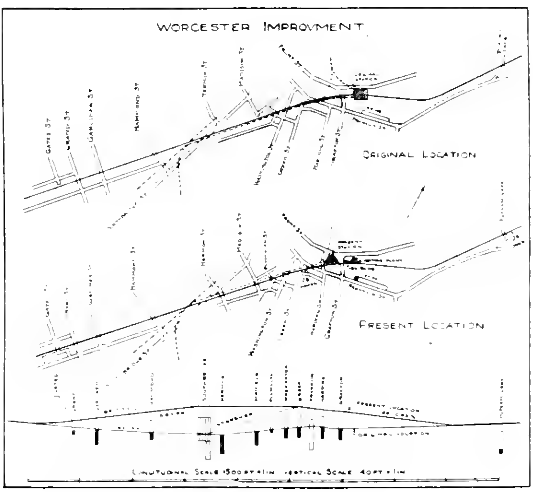

Fig. 1.

The Boston & Albany R. R., entering Worcester from the west, meets the New Haven lines, entering from the southwest, at South Worcester. Originally, the New Haven location lay south of the Boston & Albany, running parallel through the city to the Union Station, where connection was made with the Boston & Maine. The decree reversed the locations of the Boston & Albany and the New Haven, and, in order to avoid a crossing of the two roads at grade at South Worcester, it placed the Boston & Albany overhead at that point.

Additional Work, on Account of Four Tracking and Yard Development.

The work called for in the decree plan, gave the Boston & Albany only two tracks west, from the station, and therefore radical changes were made in the plans to secure the possibility of a four-track layout later on, which necessitated the construction of continuous retaining walls on the southerly side of the new right of way of the Boston & Albany.

Construction.

In 1908 both the Boston & Albany and the New Haven began a portion of the work, building several bridges and walls in the westerly approaches. The Boston & Albany constructed a girder highway bridge at Gates Street, with long approaches retained by concrete walls. This was to take the place of the grade crossing at Grand Street, where a passenger subway was put through. At Gardner Street, a 50-ft. concrete arch was built, carrying the tracks across the street. A temporary grade was established for the tracks and it was not until 1912 that this detached portion of the work was reached by the advance of the general work throughout the city.

The real beginning of the improvement construction began in the spring of 1909, when a contract for the Union Station was let. All the buildings on the site had been removed and a large part of the foundations could be put in without disturbing the operating tracks of either of the railroads. These tracks, however, had to be removed from Grafton Street to South Worcester in order to permit the work on the walls and bridges called for by the plans. It was decided to lay temporary tracks (two main tracks for the Boston & Albany and two for the New Haven) as far to the south as possible. This would clear the field for all the work of the New Haven on its new, or northerly, location. This work finished, trains of both roads were to run over it, thus releasing the south side where the Boston & Albany work lay.

Shortly after the contractors began work on the station foundations, work started on the retaining wall construction,

along the south right-of-way line. This was made necessary by the fact that for part of the way the old tracks were on embankment and to move them over to a temporary location near the south right-of-way line at their old elevation required either a trestle or filling retained by walls. Inasmuch as walls were ultimately to be required, it was clearly best to put in such part of them as would be necessary to take care of the temporary tracks. Accordingly, the lower portion of the final section was built, brought up to the temporary track grade and left ready to be topped out later. As left, the top of the concrete was provided with two longitudinal grooves, or rabbets, and, in in addition, pieces of rail about 10 ft. long were embedded at an angle, the same as the batter of the back of the wall. These rails were 5 ft. apart and projected from the temporary top of wall 3 to 5 ft. When these walls were completed to full height longitudinal rods were placed in them and fastened to the rails.

To serve the temporary main line tracks mentioned above, a temporary shelter and platform for passengers were built outside and south of the old Union Station.

During the demolition of the old train sheds, passengers used a temporary covered passageway from the headhouse to the temporary platform. It was necessary to remove the old sheds while operations were made over temporary tracks, because the permanent high level approach from the east to the new station lay where the Boston & Albany trainshed stood. This temporary track location and station went into service in August, 1909, leaving the field entirely clear for work on the new Union Station and for all the New Haven work, as well as the new steel viaduct west of the station, by which that road connected with the Boston & Maine. The Boston & Albany was also permitted to grade its easterly approach to the new station, remove the old trainshed, and lay tracks on the upper level, at and east of the new station.

In connection with the station a portion of the 60-ft. arch over Grafton Street was erected, sufficiently wide to carry two tracks. Street traffic on Grafton Street had been diverted to a detour at the time the temporary low level tracks were put into service, so that no interference was caused to the arch work.

So confined was the available width for Boston & Albany tracks at the Union Station, that it was necessary to retain the filling for the two first high-level tracks by means of a tie crib, in order to keep the slope back from the temporary low-level tracks.

The New Haven now put in reinforced concrete arches over Hermon, Madison, Plymouth and Green streets, girder bridges over Washington and Franklin streets, and the four-track steel viaducts at the station. Retaining walls were built from Plymouth Street to the station, filling was dumped and tracks laid.

The last portion of the New Haven work to be finished was the concrete slab on the viaduct. This was put on during the winter of 1910–11 and precautions were taken to prevent freezing. Underneath, a platform carrying salamanders and enclosed by canvas was hung. A shelter was erected above, at the same time, and, in addition, all materials were well heated.

The new Union Station was opened for service on Sunday, June 4, 1911, complete, except for the intertrack platform and canopy on the Boston & Albany side, with the subways running to it. This work could not be done until the temporary low-level tracks were out of the way. On the day mentioned, tracks were cut and swung to South Worcester on the west, and at Tower No. 26 on the east, so that trains took the approaches to the upper level and all used the New Haven tracks between South Worcester and the new station, as before explained.

Space for the Boston & Albany work between South Worcester and the station was now free, and all tracks were removed except one, which was left to supply the masonry contractors with materials. This track had to be shifted from time to time as the work demanded, and short sidings were run out of it at points where considerable concrete was to be placed. The masonry contractors worked night and day during the first five months, running from five to seven mixers. A switching engine was assigned by the operating department to deliver cars of sand, stone and cement to the work and remove empties. The contractors used locomotive cranes for the excavations, placing the material in location for permanent fill. The concrete was,

in general, handled by small dump cars running from the mixer to the work on a narrow-gage track and pushed by hand, except where the height of the wall necessitated raising, which was accomplished by building a light trestle for the narrow-gage track and pulling the cars by cable and engine.

West of South Worcester, the two main tracks of the Boston & Albany were moved laterally north, far enough to allow the building of the south walls and the placing of filling for one high level track, the slope from which had to be retained by a cribbing of old ties. Practically all the masonry and steel for bridge No. 61, which carries the Boston & Albany over the New Haven at South Worcester, could be put in along with the other work. Retaining walls were built practically all the way, there being only two points where enough land was owned for an earth slope. The highest wall was 47 ft. All walls are gravity section of 1:3:6 concrete. No piles, or other special foundations, were necessary, except at the end of the west abutment at Franklin Street.

In general, the scheme of work was directed toward the preparation of sufficient masonry and partial bridge structures to carry one construction track through on the upper level. Early in the spring of 1912, this point was reached, and filling began. The material for this was taken out of a large bank east of the freight yard by steam shovel, and carried by standard-gage trains. In some cases streets had to be crossed by trestles, but in most the construction track was carried on permanent bridge girders or on completed portions of arches. With filling trains running at frequent intervals, it was quite difficult to serve the masonry and steel contractors with material from the same track, but the time of congestion was comparatively short, and as soon as a portion of the distance could be furnished with a second track, no further interference was encountered. The old supply track on the low level, was, of course, taken up, and the last portion of the masonry was finished by plant set up on the upper level.

Permanent track laying began before the entire fill had been finished, and while many of the bridge slabs were under construction. For a portion of the way the high-level construction track was made to serve as main line when traffic in one direction

was run upon the upper level. This took place in June, 1912, and a month later the other was changed. West of South Worcester, there still remained some bridge masonry and considerable filling, which could not be put in until all tracks on the low level were taken up.

All Boston & Albany traffic was now running on the permanent upper level, but only a portion of the permanent track layout and none of the electric signals and interlocking was in place. In completing the full layout of tracks and in finishing the concrete slab floors on bridges, it was necessary to shift trains from one track to another a great number of times and to cut track often for the purpose of putting in turnouts and crossovers. Along with the final work of track laying, ballasting and signaling, went the construction of intertrack platforms and canopies at the station, while the city street department executed the street excavation and paving necessary to conform to the changes ordered by the decree.

The following bridges were built in the elimination of grade crossings and other improvements at Worcester, Mass.:

Bridge	No.	56,	Grafton Street
,,	,,	57,	Harding Street
,,	,,	59,	Franklin Street
,,	,,	59A,	Green Street
,,	,,	59B,	Washington Street
,,	,,	60,	Plymouth Street Subway
,,	,,	60A,	Madison Street
,,	,,	60B,	Hermon Street
,,	,,	61,	Southbridge Street, N. Y., N. H. & H. R. R.
,,	,,	61A,	Hammond Street
,,	,,	61B,	Gardner Street
,,	,,	61C,	Grand Street
,,	,,	61D,	Gates Street

Bridge No. 55, Putnam Lane, was reconstructed also, in connection with the improvements.

All the above bridges were divided into two types; concrete arches reinforced with steel, and deck plate girders with reinforced concrete slabs. All the arches and reinforced slabs were covered with waterproofing protected by a course of tile or brick, and upon this placed the fill, stone ballast and tracks.

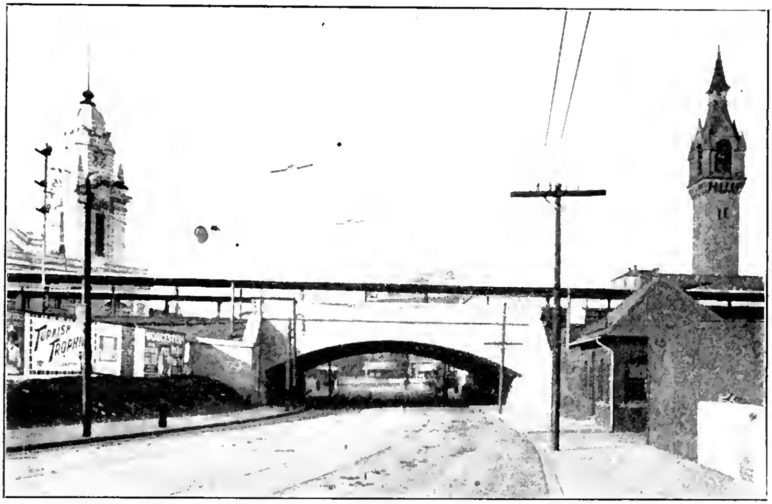

FIG. 2. GRAFTON STREET BRIDGE.

Bridge No. 56, Grafton Street:

This bridge is situated over Grafton Street, just east of the station. It has a clear span of 60 ft. between springing lines, with a rise of 7 ft. 6 in. The thickness of the arch at crown is 3 ft. On account of the small rise it was found necessary to construct the foundations of the abutments so as to bring resulting pressure normal to the soil and in this way reduce the pressure per square foot. At the north side an overhanging platform was built to provide an extension of the station platform to allow for the passage of trucks between the American Express building and the station. A concrete railing was built at each end and divided into panels to relieve the bare effect of the concrete and also to harmonize with the architecture of the station. The railing was constructed with expansion joints and anchored securely to the structure by vertical rods.

Bridge No. 57, Harding Street:

This bridge is over the extension of Harding Street, and carries five tracks and two platforms. The structure under the tracks consists of deck plate girders encased in concrete, forming a solid slab.

The top of the slab is waterproofed and covered with brick, on which is placed the ballast and track. The portion of the structure under the platforms consists of reinforced concrete beams and slabs resting on deck plate girders. In the platforms vault lights were also constructed to supply light to the street beneath. The south half of the west abutment of this bridge is constructed on piles, the north half on spread footing, in the bottom of which rails were placed. The east abutment is directly over the reinforced arch which covers Mill Brook canal. This arch as originally built was of brick construction. This portion was left in place and a reinforced concrete arch built outside of it, of sufficient strength to carry the weight of the abutment.

Bridge No. 59, Franklin Street:

This bridge carries five tracks over Franklin Street. The clear width between abutments is 40 ft.; distance from base of rail to bottom of foundations is 33 ft.; and angle of skew between center line of street and center line of track is 26 degrees. The intersection of street and property lines at southwest side of bridge is such that abutment and retaining wall meet so as to form a wedge. On this wedge-shaped portion of the abutment, it was necessary to carry a load of 750 tons, which is the reaction from the facia girder. To avoid overloading the soil at this point, a heavy steel column was enclosed in concrete in the abutment to carry the heavy reaction down to a spread footing 15 ft. by 21 ft., consisting of grillage of steel beams encased in concrete and built on pile foundations beneath the foundation of the main abutment.

The clear width between street lines is 40 ft., but on account of the extreme skew it was necessary to make facia girders at the north and south sides of bridge 108.5 ft. long. The steel work of this structure consists of two 108.5 ft. facia girders which carry the ends of other girders of varying lengths located at right angles to the street, the two facia girders being parallel to the direction of the track. The regular floor girder is 45 ft. long, spanning the entire opening. The long facia girders required a gross flange section of about 220 sq. in., made up of two vertical side plates,

four 8-in. by 8-in. by 1-in. angles, with additional vertical side plates and completed with six cover plates of varying lengths. The web consists of a 120-in. by $\frac{5}{8}$-in. plate reinforced at the heavy end of the girder by a 120-in. by $\frac{3}{4}$-in. reinforcing plate. The 8-in. by 8-in. by 1-in. angles were furnished full length for these long facia girders, no splice being necessary.

On account of the varying length of the floor girders, the loads carried to the facia girders vary at different sections. One end of the facia girder receives live load from three tracks, while the other end receives a live load only from one track.

The floor of this bridge consists of a reinforced concrete slab resting on the top flanges of the floor girders. This slab was covered with waterproofing and a protection course of brick, on which was placed the ballast and track. The 108.5 ft. girders weigh 108 tons each. They have cover plate width of 27 ins. and a depth of 10 ft., and were shipped from the bridge shop to site in one piece.

The total weight of the steel in this structure is 1 105 250 lbs.

Bridge No. 59 A, Green Street:

This bridge has a clear span at right angles to center line of street of 72 ft. 2 in. between springing lines, making a span on the skew parallel to the tracks, of 82 ft. $8\frac{3}{4}$ ins. The rise is 9 ft. On the layout of tracks, in accordance with the original diagram, it was intended to make a reinforced concrete arch at this point, but owing to the necessity of widening the bridge for additional tracks, to the fact that it was only 1 ft. between the top of arch and the base of rail, and that it was necessary to omit the portion of the east abutment adjacent to the New Haven tracks, in order to provide for a stairway from the street to the station platform, it was decided to use a steel rib arch, encased in concrete. Owing to the flatness of the arch, the abutments were constructed on lines similar to those of Bridge No. 56. After the abutments had been completed, cast-steel shoes were set in the proper positions on the bridge seats, and the steel ribs erected. Each rib was shipped in two sections with a field splice at the crown. After all the steel ribs and diaphragms had been placed, the steel columns supporting transverse girders were erected

and all steelwork was wrapped with rods and mesh and encased in concrete. The reinforced concrete slab floor was then constructed and this floor was covered with waterproofing and protection, with ballast and track laid upon it. Owing to the fact that the east abutment had to be terminated at the corner of Green and Temple streets, and in order to keep outside of the street lines, it was not possible to carry the steel rib construction far enough south to take care of the southerly track. In order to provide for this track, a plate girder extending from the west abutment past the corner of the street to the retaining wall on Temple Street was built and transverse floor beams built between the southerly rib and this girder. The floor beams and the girder were encased in concrete and the floor slab extended to the girder.

The total weight of steel in the superstructure is 1 329 450 lbs.

Bridge No. 59 B, Washington Street:

This structure is similar to Bridge No. 59. The clear width of street is 40 ft., but the angle of skew is much less, making the facia girders only 70 ft. long instead of 108.5 ft., as in the case of Bridge No. 59. This bridge carries four tracks.

The total weight of the steel superstructure is 380 348 lbs.

Bridge No. 60, Plymouth Street Subway:

This is a subway for pedestrains only. It consists of abutments of gravity section with a reinforced concrete arch, the faces of which are finished in cut granite. The entire subway is lined with glazed brick.

Bridge No. 60 A, Madison Street:

This is a reinforced concrete arch, the crown thickness being 2 ft. 6 in., clear span 50 ft. between springing lines, and rise 7 ft. 6 in. The foundations of the abutments were constructed similar to those of Bridge No. 56. Under the south parapet wall the arch ring was made thicker at the crown in order to carry the increased pressure due to the retaining wall action of the parapet.

The arch was waterproofed and covered with protection, and tile drains were placed behind the parapet walls the same as back of retaining walls.

Bridge No. 60 B, Hermon Street:

The construction of this bridge was practically the same as that of Bridge No. 60 A.

Bridge No. 61, Southbridge Street, New York, New Haven & Hartford Railroad:

This structure, which is built to accommodate four tracks, spans Southbridge Street and the tracks of the New York, New Haven & Hartford Railroad, and is divided into 5 spans, the total length being 725 ft. 6 in.

The span over Southbridge Street is 161 ft. 8 in. long, center to center of bearings. The next span west of Southbridge Street is 105 ft. 9 ins. out to out of steel on the north girder and 102 ft. and 76 ft. on two south girders. The next span over the first two New Haven tracks is 122 ft. 4 ins. for the north girder and 109 ft. 7 ins. for the south girder. The girders of the extreme west span are 122 ft. 6 ins. long.

The total weight of steel in this structure is 4 320 tons. The heaviest single piece weighs 170 tons. The other girders range from 136 tons to 69 tons. The span over Southbridge Street consists of deck riveted trusses surmounted by an I-beam floor. The entire structure is covered with a reinforced concrete slab, completely waterproofed and covered with ballast.

The structure is drained by forming ridges and valleys of cinder concrete on top of the slab, to carry the water into the drains in the piers and abutments. The substructure consists of gravity section abutments and solid concrete piers, except the west pier, separating the New York, New Haven & Hartford Railroad Company tracks, know as pier " E," which, on account of close spacing of the tracks, was constructed of steel columns and girders encased in concrete. The columns were carried down beneath the level of the tracks to rest on I-beam grillages made sufficiently large to distribute the heavy loads from the ends of the facia and cross girders. The entire under portion of the

bridge over the tracks is encased in concrete, and the area directly above the rails is covered with a one-inch glazed tile to resist the exhaust of the locomotives.

Bridge No. 61 A, Hammond Street:

The superstructure of this bridge, which is located over Hammond Street, consists of deck plate girders on which is constructed a reinforced concrete slab. This bridge is similar to Bridges Nos. 59 and 59 B.

The total weight of the steel is 372 284 lbs.

Bridge No. 61 B, Gardner Street:

This is an overhead bridge consisting of through plate girders with a concrete floor spanning four tracks. There are two graded approaches, one from east and one from west, on the south side of the bridge.

Bridge No. 61 C, Grand Street:

This is a subway of similar construction to Bridge No. 60.

Bridge No. 61 D, Gates Street:

This is a concrete arch, reinforced with steel similar to Bridge No. 56. This is one of the bridges which were constructed in 1909.

Summary of weight of steel work in superstructures of Worcester bridges:

Bridge No.	55,	Putnam Lane	194.8 tons
,, ,,	57,	Harding Street	181.4 ,,
,, ,,	59,	Franklin Street	552.6 ,,
,, ,,	59A,	Green Street	664.7 ,,
,, ,,	59B	Washington Street	190.2 ,,
,, ,,	61,	Southbridge Street	4,420.0 ,,
,, ,,	61A,	Hammond Street	186.1 ,,
,, ,,	61D,	Gates Street	102.0 ,,
			6,491.8 tons

Some of the materials which were used to a considerable extent in connection with the improvement work, were, concrete, 150 000 cu. yds.; foundation excavation, 60 000 cu. yds. reinforcing steel, 500 000 lbs.; filling, 400 000 cu. yds.

Signals.

Train operation is controlled by two interlocking towers. One is a 96-lever, all-electric plant located at Green Street, operating all main track switches and switches from yard tracks to main tracks, the longest distance between tower and any switch being 2 000 ft. Both ends of a cross-over are operated by one lever and are operated in two seconds. Approach locking is in use and also route locking with trailing release, no detector bars being used. The operating current for the switches and signals is supplied from a 65-cell, 400-ampere-hour storage battery, which is sufficient to operate the plant for ten days without recharging. During charging the battery floats on the charging current and still operates the plant. The electric locks and track model are supplied with current from a 6-cell, 400-ampere-hour storage battery in duplicate. Each set of batteries is capable of operating the locks and model for three days without recharging. While one set of batteries is on discharge, the second set is charged. The main operating battery is charged from a 175-volt, 50-ampere mercury arc rectifier, operated from 220-volt A. C. supply. The lock batteries are charged from a 40-ampere, 20-volt motor generator set from 440-volt A. C. supply. The switchboard for the distribution of the power is the largest and most complete of its kind for D. C. interlocking work yet made by the General Electric Co.

The signals are of the upper quadrant type and operate on 110-volt D. C. High signals are top-post, Hall style K; dwarf signals are of the solenoid type. Signals are electrically lighted, normally on 110-volt A. C., but in case of failure of the supply, can be immediately switched to the main battery D. C. supply.

The interlocking at the east entrance to the freight yard and station tracks is a 60-lever, mechanical, style A plant. Approach and route locking with trailing release are installed throughout the plant, no detector bars being used.

All signals and electrical apparatus are operated from storage batteries charged from a motor generator set, located at Tower 28. High signals are of the top-post, Hall style K, 10-volt type. All signals at this point are also lighted electrically,

normally from 110-volt A. C. supply, but, in the case of emergency, can be switched to main battery D. C. supply from Tower 28. No track model is installed at this plant. Each signal has its own repeater and each track circuit its own indicator. The reason for this is that additions to this plant are likely in the near future, and additions to a track model are difficult to make and still preserve the general yard appearance of the model.

The westbound distant signal for Tower 26 is located 4 879 ft. east of the home signal.

To eliminate the necessity of check locking between towers, automatic signals for all tracks are installed on a six-track signal bridge, 2 279 ft. west of eastbound home signal for Tower 26, and 2 094 ft. east of last eastbound home signal for Tower 28.

These automatic signals are used also as distant signals for each tower, but on account of the distance being less than 4 000 ft. from home signal the distant indicator is repeated by the 90-degree indicator of the home signal to the rear in each direction. Particular attention was paid to locating all signals where the view to enginemen would be unobstructed, and special supports were designed and erected where needed to accomplish this object.

General Heating Plant.

Building: 47 ft. 4 ins., by 65 ft. 4 ins. inside. Twenty-nine ft. to under side of trusses.

Coal Pocket: 28 ft. 9 ins. wide by 48 ft. 10 ins. long, by 11 ft. 6 ins. clear under beams.

Equipment: Two hundred h.p. Robb-Mumford water tube boilers equipped with Jones underfeed stokers; Cole automatic control; forced draft fan, run by an engine, automatically controlled by steam pressure in boiler.

Auxiliaries consist of two 7 by $4\frac{1}{2}$ by 10 Platt Iron Works duplex feed pumps, and one 200 h.p. Webster open-feed water heater.

Chimney: 5 ft. diameter at top, 125 ft. high, built of red radial brick, by Alphons-Custodis Chimney Construction Co.

From the central heating plant, steam is furnished for

heating the new Union Passenger Station, for all cooking in the station, for heating the old head-house of the old station, the American Express Company's building, coaches in coach yard east of the central heating plant, and Pullman cars on the Pullman tracks.

Steam is supplied to the station for heating and cooking through a 4-in. medium pressure steam line at 40 lbs. pressure. This line is carried through the head-house of the old station and then underground for about 400 ft. In the basement of the station, the steam is reduced to about three or four pounds pressure for heating, and to about 25 pounds for cooking and heating water.

A $1\frac{1}{2}$-in. auxiliary steam line is laid with the 4-in. main steam supply line and the $2\frac{1}{2}$-in. return line for supplying steam for cooking purposes in the Union Station during the summer months.

Condensation from the heating and cooking system is returned to the central heating plant by a duplicate set of 6 by 6, motor-driven vacuum pumps manufactured by Warren Steam Pump Co., pumping into a Webster receiving and vent tank overhead in the station, placed high enough so that the water is returned by gravity, following the same route back underground and through the head-house to the feed water heater in the central heating plant.

Water is heated in the open feed water heater by exhaust steam from fan, engine and pumps. The entire drip system on the steam mains, including drips from coach yard, is returned into this heater at a very high temperature, able to maintain a feed water temperature of 180 to 200 degrees.

The coach heating capacity is for about forty-five cars. The excavation on the building was started August 21, 1911. Steam was turned into the station from the central heating plant on the night of December 4, 1911. Previously, the station heating was taken care of by temporary horizontal tubular boilers, erected in the New Union Station.

Freight House Extension.

Size, 95 ft. by 50 ft. Two stories high. Heating plant in basement at one end. Second floor hung from roof trusses.

First story, cashier's office, warm room, bonded space, toilet and general freight.

Second story, clerical force and files.

Exterior, common brick; second floor and roof of concrete. Steel roof trusses.

American Express Building.

Location parallel to tracks and fronting on Grafton Street, two stories high; concrete foundations; face brick with terra-cotta cornice and cast concrete belt course and sills. Size, 66 ft. by 58 ft. on Grafton Street, with ell 98 ft. by 30 ft. No columns on ground floor; 20-in. I-beams for girders; wood joists; 2-in. plank floor and roof; electric elevator; heat from central power plant. Teams back up to twelve delivery openings on ground floor. Public office and entrance on Grafton Street side — ground floor.

General.

The work was carried out successfully, due to the coöperation of all departments and the authorities of the city, particularly the office of the City Engineer. The cost of the work was approximately $4 500,000.

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PAPERS AND DISCUSSIONS

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DISCUSSION OF THE MECHANICS OF REINFORCED CONCRETE UNDER FLEXURE IN BEAM AND SLAB TYPES.

BY E. S. MARTIN, J. R. WORCESTER, L. J. JOHNSON, S. E. THOMPSON AND H. F. BRYANT.

MR. E. S. MARTIN,* Asso. M. Am. Soc. C. E.— At the beginning of the paper, the statement is made,

"The bond shear is zero wherever the tension in the steel is constant. It passes through zero where the increment of the moment passes through a maximum or minimum."

What is meant is, that when the moment passes through a maximum or minimum the bond shear is zero.

Farther on in Mr. Turner's paper, it is stated:

"This ratio, or lateral effect, in a combination of steel and concrete which is sufficiently fine grained to be regarded as acting like a homogeneous material, as is the case with reinforced concrete slabs, cannot be correctly considered as an elastic property of either the concrete or the metal, but on the contrary must be treated as a coefficient expressing the efficiency of the lateral action of the indirect stresses induced by the bond shear in the case of multiple way reinforcement in the slab, etc."

I think I am justified in explaining one phrase which in my opinion may be misconstrued. It strikes me that perhaps

NOTE. Further discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, by December 10, 1914, for publication in a subsequent number of the JOURNAL.

*Owing to the absence of the author, Mr. Turner's paper was read by Mr. Martin.

those who deny that there is interaction between the belts of reinforcement in different directions in reinforced concrete slabs might take this to be a begging of the question. What Mr. Turner assumes is not that reinforcement in different belts can be treated as an actual plate of steel, but, as I understand it, this phrase means that the reinforcement is sufficiently well distributed so that the concrete slab as a whole acts as a unit. For example, a slab of 20 ft. span, 8 in. thick, which is reinforced with rods 2 in. in diameter and 8 ft. apart, would not be fine-grained. It is understood, on the contrary, that the reinforcement is sufficiently well distributed so that it has the same general properties in all parts of the slab; the reinforcement isn't concentrated so that small areas are over reinforced and other areas without any reinforcement.

Mr. J. R. Worcester (*by letter*). — The author's labored explanation of the advantages of multiple-way reinforced flat-slab construction would be much more convincing if he had not felt compelled to eliminate, for the sake of brevity, some explanations of his meaning, which seem necessary in order to make the subject intelligible to the ordinary mind.

A "circumferential cantilever," upon which his argument largely depends, is a difficult conception. If we imagine a flat slab supported upon a single post, the slab being thin enough to deform in a natural way, it would take a domelike shape, vertical sections on radial planes through which would be alike, and all taking the shape of some regular curve. It is easy to see that each radial element is a double cantilever. But, considering any circumference equidistant from the center of the post, what would be its form? Apparently it would be a ring, which, developed, would be bounded by horizontal lines. How can there be any cantilever action in this? How is there any deformation in it? A cantilever surely implies a point of support under it, but this ring has no support. The trouble with this conception is that it fails to consider that the vertical circumferential section before the slab deforms does not remain a cylinder after deformation, but becomes a portion of a cone, and the circumferential element at the top of the slab elongates while the circumference at the bottom shortens. The result

is that when we develop this circumferential section, it is not bounded by horizontal straight lines, but by curves, having the same radius of curvature as the radial elements.

The above considerations would support the author's contention that a circumferential reinforcement, where present, would be as effective as a radial, but the further reasoning by which he proves it to be many times as effective is too intricate for the writer to follow. It is to be hoped that the author will furnish some of the links in the chain which he flatters us by assuming that we can supply.

Moreover, how is it that the same bars which afford radial reinforcement can also be called upon to furnish circumferential? Possibly some bars near the outer edges of bands should be considered as acting circumferentially rather than radially, but nearer the center they must act radially, and can any act in both capacities? Granting that resistance to flexure in either direction helps to resist external moments, the only direction in which the reinforcement can resist is parallel to its direction. Though the compressive forces may diverge and interact, the tensile forces must remain in the direction of the steel, and the total tensile stress cannot exceed the total capacity of the reinforcement.

It is by no means clear how a tendency to curvature in multiple directions can decrease the total amount of tensile stresses which must be resisted.

Prof. L. J. Johnson. — After reading this paper with care, and after hearing it read, I regret to have to say that it is difficult for me to take it seriously.

I freely grant that the buildings designed by its author may be giving service. At the same time, one may well beg to be excused from accepting his explanation of their stability or his ideas on the mechanics of such structures. If his formulas give, as he states, results closely agreeing with observed steel stresses as measured by extensometers, he is clearly to be congratulated. Nevertheless, they may be, in essence, merely empirical formulas — rules of thumb, which happen to give apparently right results for the range within which they have been tested. From this point of view they are certainly worthy

of attention, but I regret to say, with all due respect, that I do not think the same of the substance of these attempts to justify them by appeals to mathematics and mechanics.

To-day one need hardly go into the details of this phase of the matter. The whole thing has been given a pretty thorough airing in the American Society of Civil Engineers. Mr. John R. Nichols, of that Society, in a paper presented in May, 1913, and printed in the Proceedings of the April preceding, pointed out the clear incompatibility with the unquestioned principles of statics of important contentions of the promoter of this system. The discussion which followed brought out, in my judgment, no substantial rejoinder, and Mr. Nichols in his closure — not yet in print but which I have had the privilege of seeing in manuscript — pressed his points still further home. The gist of his paper is a demonstration that what we may call the modulus of reinforcement (or measure in terms of load and span of the required reinforcement) of a slab of Mr. Turner's usual type could not even, under the most favorable conditions, fall below $\frac{WL}{12.9}$ as against the $\frac{WL}{50}$, which has hitherto been a prominent value for this quantity in Mr. Turner's writings. In order to provide the usual margin against tension in the concrete, or overstressing the steel, the modulus — for this type of reinforcement — would have to be taken much greater than even $\frac{WL}{12.9}$.

It is interesting to note that in the paper before us this evening Mr. Turner makes no reference to $\frac{WL}{50}$, but now mentions $\frac{WL}{30}$ for what seems to be meant for the same quantity.

Entirely apart from what statics admittedly cannot do toward the solution of the slab problem, it can at least demonstrate that certain things cannot be true. For example, statics cannot tell us just how the pressure is divided among three supports of a horizontal beam, but it can nevertheless tell us that on at least one of the three supports the pressure must be at

least one third of the load, that any statement to the contrary is certainly wrong, as well as the reasoning behind it, however subtle. Mr. Nichols's results come from an analogous and equally simple and convincing use of statics and are results to which any theory of slabs must conform however derived. His papers should accordingly have the careful attention of students of the slab problem.

In a word, I believe the explanation of stability in these flat-slab buildings is to be found not in the subtleties advanced by Professor Eddy and Mr. Turner, but in good concrete furnishing tensile strength; to arch or dome action; to a more plentiful supply of steel than $WL \div 50$ or $WL \div 30$ would call for; to only interior panels being loaded for tests; or to some combination of all these. I do not think it is due to anything out of the range of our ordinary thoughts, and certainly not to such causes as are suggested in the paper of the evening.

Sanford E. Thompson. — I agree with Mr. Turner that the question of flat-slab design is not generally understood, and, in view of the widespread adoption of flat slabs of various types, any information which throws light on the theory or practice of their design is of value. Mr. Turner's comparison of a flat slab with a mechanism with its storage reservoir of energy is interesting, but I question whether the substitution of this for a theory based strictly on principles of statics may not tend to confuse the reader.

In the first part of the paper, Mr. Turner compares the rigidity of the lineal cantilever with that of a circumferential cantilever with four-way reinforcement, and arrives at the conclusion that it would require four times the load to produce the same deflection with a circumferential cantilever as it would with a lineal cantilever of the same dimensions. Mr. Turner's conclusions are based on the assumption (if we translate Mr. Turner's terms into terms of statics) that half of the bending moment is taken in the circumferential and half in radial directions. Mr. Turner does not substantiate this assumption. Theories dealing with circumferential cantilevers teach us that the distribution of the bending moment depends upon the Poisson's ratio, which in turn depends upon the character of the material. In

no case, however, does the circumferential moment exceed about 50 per cent. of the radial bending moment.

The conclusion that the circumferential cantilever is four times as strong as the lineal cantilever appears to be unsubstantiated, not only because the assumption as to the bending moments appears to be incorrect, but also because it considers that all the bars in the bands are equally effective. Tests made with the use of extensometers show conclusively that the bars in a band do not participate equally in taking the bending moment. The stresses in the bars right at the column head are about twice as large as the stresses in the outside bars in the same band. Therefore, if the elastic limit of steel is 32 000 lbs. per sq. in., the cantilever would fail at an average stress of 24 000 lbs. per sq. in. because with this average stress the bars near the center would be stressed up to the elastic limit. In designing such cantilevers, this uneven distribution of stress and steel through the band must be taken care of either by using lower unit stresses than the allowable, or by assuming only a portion of the bars as effective. The subject of such cantilevers has been very well treated by Professor Talbot, in his Bulletin on Reinforced Wall Footings and Column Footings.*

In spite of the fact that the conclusion as to the ratio of strength of a simple cantilever and a cantilever with four-way reinforcement is based on the doubtful assumption, "If half our energy is stored circumferentially and half radially," Mr. Turner uses this ratio in the latter part of his paper as an exact figure, and by further multiplication thus gets for the bending moment at the support the value desired.

Tests show that the bending moment at the column head is actually much larger than the bending moment recommended by Mr. Turner, and therefore the stresses in steel larger than would be obtained on the basis of his bending moment. This may be seen by referring to Professor Eddy's recent paper on "Steel Stresses in Flat Slabs," presented before the American Society of Civil Engineers.

In my discussion of a paper I have called attention to the

* University of Illinois Bulletin No. 67, "Reinforced Concrete Wall Footings and Column Footings," by Arthur N. Talbot.

fact that for the working load of the slab in the tests described by Dr. Eddy the stresses in certain points were very close to the elastic limit of the steel and therefore unsafe.

Mr. Turner says, "Certainly a theory such as that of Dr. Eddy's, which enables us to compute deflections accurately and which gives the steel stress in accord with experiment, cannot be lightly dismissed." There are two tests published in which Professor Eddy attempted to compare the stresses obtained from his formulas with the actual stresses. One was the test of the Northwestern Glass Company building mentioned above, where the stresses for his formulas, as shown by my discussion referred to above, did not agree within 50 per cent. with the actual stresses; and the other instance is a breaking test which was not carried on in such a way as to give the largest stress.

Attention must be called very clearly to the misleading conclusions that may be derived when the load is placed on one panel so that the load, instead of being carried by the tested portion alone, is partially carried by the adjoining panels, and consequently does not produce so high stresses at the column head as would be obtained with full loading of a floor. Unfortunately, most of Mr. Turner's published tests were made with this type of loading. This does give the greatest stress in the center of the panel and may have been purposely selected with this end in view, as I believe Mr. Turner formerly considered the center as the position of maximum stress in the slab.

It should be noted also that the column head used in Mr. Turner's test to destruction, which was used by Professor Eddy as a basis for his formulas, was much larger in size than the column head used by him in actual construction, although the results of the formulas based on that experiment Professor Eddy assumed to apply to slabs in actual construction. The ratio of the diameter of the column head to span in the test was 0.29 with a square head, while in practice a ratio of less than 0.2 is used by Mr. Turner with a circular column head.

In other words, the span of the test slab was 12 ft. 0 in. with a column head 3 ft. 6 in. square (area, 2.25 sq. ft.; maximum diameter, 4.9 ft.), while the Northwestern Glass Company building with 16 ft. 0 in. by 17 ft. 0 in. spans had smaller cir-

cular column heads, these being 3 ft. 4 in. in diameter (area, 8.7 sq. ft.). It is evident that formulas developed for one case cannot apply to the other case, and that this breaking test does not in any way represent the strength of the system.

The theory of statics determinate or indeterminate, as the case may be, is sufficient, we believe, to deal with all structures in equilibrium, without borrowing from mechanics of motion with its reservoirs of energy. In fact, Dr. Eddy's original theory, presented in 1899 and based on pure statics, stands, I believe, as the best exposition of the problem. In a structural member, the strength is measured by the strength at the weakest point rather than by any energy stored within the member. In flat-slab design, if steel or concrete is overstressed right at the support, or if the diagonal tension is exceeded, failure may occur no matter whether or not the bands of steel represent stored energy.

I looked up, this afternoon, the article by George Hill, in the *Architectural Record*, to which reference is made in the paper. I fail to find any connection whatever between the structure referred to there and flat slabs as they are built to-day by any designer. I should be glad of further information on this point.

Mr. H. F. Bryant. — I have great respect for Mr. Turner's flat slabs. Some years ago I devoted myself most earnestly to trying to analyze his theory, but was unsuccessful, and I haven't been able to obtain any further light from this paper. This may be because I am dull, but it certainly didn't appear to me as definite and final.

I do think that the majority of his floors that I have seen, and some of those which I have built, indicate that unless the elastic limit of the steel at the column head is high there is some evidence of failure, that is, most of those slabs which are built with ordinary mild steel have shown constantly increasing deflections, while there are no signs, perhaps, of failure. Mr. McCullough of Chicago has said that he thinks this a phenomenon that takes place in all structures — at any rate in all concrete structures — where mild steel is used; i. e., that the steel flows slightly where the stress is below the elastic limit of mild steel, usually given as 33 000 lbs. I have generally used high-carbon

steel where possible, and usually deformed steel at that, and where this has been done have had no trouble. I believe Mr. Turner's practice is similar, and I think it a very safe one. It will help his theories out almost any time.

So far as tests go, I have made several tests of flat slabs. A 7-in. interior flat slab, columns 16 ft. on centers, if I remember rightly, was tested with 450 lbs. per sq. in. I think the reinforcement was $\frac{3}{8}$-in. corrugated square bars, 6 in. on centers, using the usual 16 rods to the band. The slab, which was designed to carry 200 lbs. per sq. ft., showed very little deflection and no signs of failure. I would like to have somebody really explain this. I don't think Mr. Thompson's theory of the time, which I looked up with some care, would account for it. I don't see anything rational and definite to account for the structure standing up. It is beyond me, and I would like to have it explained better than has yet been done.

Mr. E. S. Martin. — I think it is entirely in order for me to explain, for instance, what this George Hill construction was that Mr. Thompson inquired about and which wasn't fully stated in the paper. That write-up he gave the *Architectural Record* I believe left out some details. The construction was practically the same as the Bridgewater structure, except that the columns were spaced about twice as far apart. It was reinforced with expanded metal in the same general way. The building of George Hill and the reservoir that he speaks of both failed and additional piers were added so that the span was reduced to 8 ft. with practically a 12-in. slab. The roof of that building is supported on cast-iron columns and brackets, and has cracked and faulted two or three inches in some places.

Regarding the relative magnitude of the radial and circumferential stresses, I believe that it is very easily shown that the radial and circumferential stresses must be equal. That is, the curvature of this cantilever portion is exactly the same circumferentially as radially, therefore the stresses must be the same at the same point. That doesn't mean that the outer rods of a belt have the same stresses as the middle rods which pass over the cap, but the middle rod, for instance, where it crosses the outer rod of the rectangular belt, would have the

same stress. That is, I believe, approximately found true by extensometer measurements, and it is absolutely true according to theory, because the curvature of this cantilever portion geometrically requires that it must be equal. This is sometimes explained by a diagram which shows an exaggerated condition of flexure of this cantilever portion of the slab. As the radii of the top surface are increased, it is seen that the circumferences are also in the same ratio. From the reference by Mr. Bryant to high-tension steel, do I understand that we advocate high-tension steel? I just want to state that we have used high-tension steel in some cases, but on every building which I have designed since I have been in the Eastern states we have used medium steel.

May I call attention to this fact, which I know Mr. Turner has published at least in some of his discussions that I have seen. He has called attention to tests made and published by Professor Talbot in one of the bulletins of the University of Illinois Experiment Station, on three large beams, I think, a couple of years ago, built and tested for the Illinois Central Railroad, in which he shows that the tension in the concrete is effective only for low stresses and low loads and that the steel as Mr. Nichols stated is stressed at less than half what the computed stress was on the basis of no tension in the concrete. With the working load designed for 16 000 lbs. per sq. in., the actual stresses measured were about 10 or 15 per cent. less. Up to 20 000 lbs. it is almost identical.

Vol. I DECEMBER, 1914 No. 10

BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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THE PHOSPHATE ROCK INDUSTRY OF FLORIDA.

By Lester W. Tucker, Member Boston Society of Civil Engineers.

(Presented June 10, 1914.)

One of the industries of the state of Florida, of which very little is seen by the average tourist, is that of mining phosphate rock. Such a traveler going into the state for the purpose of escaping the cold and disagreeable winter climate of the North cares little for industrial matters, and if by chance he passes through a region of great activity, where steam shovels are tearing up the earth, where locomotives and cars are moving about in all directions and where modern power houses rear their tall stacks in the air, he may wonder momentarily what is going on in this land of sunshine and rest and then pass on to be absorbed by pleasanter scenes and thoughts.

The average person thinks of Florida as one vast winter vacation country, and yet within her borders lie some of the important industries of the United States. Her naval stores have been, and are now, of vast importance; her timber industry has been of great value in the past, but is now on the decline; her citrus crops are increasing year by year; her truck gardening has grown in the last twenty years to such vast proportions that to-day she supplies practically the whole of our eastern country with vegetables and garden truck during the winter months;

Note. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before February 10, 1915, for publication in a subsequent number of the Journal.

her winter hotels are well known for the luxury of their appointments and the excellence of their cuisine; but beyond all these, the one industry of greatest value to the country as a whole is that of mining phosphate rock.

History.

Phosphate rock in considerable quantity has been found in the states of South Carolina, Florida, Tennessee, and in small beds in other southern states; also in Arkansas, Utah, Wyoming, Idaho and other states west of the Mississippi. The production of some of the more important states will be taken up and considered separately.

South Carolina. The discovery of phosphate rock in South Carolina, and the first of importance in the United States, dates back to 1858, when the beds along the Wando River were discovered, but, owing to the breaking out of the Civil War, no attempt was made to work them until the year 1867, when six tons of rock were mined. The production steadily increased until it reached its maximum of 541 645 long tons in 1889. Since 1889 there has been an almost steady decline, 257 000 tons having been produced in 1910, and everything now indicates a continued steady decrease, due to the apparent exhaustion of the beds.

The beds in the state of South Carolina occur interruptedly in a belt extending from a point near the mouth of the Wando River, in Charleston County, to the mouth of Broad River. As a general thing this belt lies comparatively near the coast, although in places it extends as far back as twenty miles. As these beds are now being worked, their complete exhaustion is only a matter of a few years. The diagram showing the annual production of rock in the United States (Fig. 1) shows graphically the decline of the industry in this state.

Tennessee. The deposits in Tennessee were discovered in 1893 but were not mined to any extent until 1897, when about 130 000 long tons were taken out. The deposits are located mainly in Maury, Hickman, Perry and Lewis counties, with smaller deposits in several of the adjoining counties. The production in this state increased from 1897 to its maximum in

1907, when 639 000 tons were taken out; but since that time there has been a diminution in the amount of rock mined, for in 1909 it was only 333 000 tons. Since 1909 there has been a slight advance in production. In 1910, 398 000 tons were mined, and in 1911 about 430 000, with a slightly less amount in 1912; and from this it would appear that the production of Tennessee rock may have had only a temporary slump and that it may be again on the increase.

Western States. The production of phosphate rock in the states west of the Mississippi River has been of very slow growth. Nearly all that country is new, the soil is not exhausted and the use of fertilizer, except for some special crops, is not required. In 1903 about 400 tons were mined in these states, and this gradually increased until, in 1907, 48 000 tons were produced. Since that time there has been a falling off until, in the year of 1912, only about 10 500 tons were produced. About all the rock mined in this section is used on the west coast, there being a few small fertilizer factories located near Los Angeles and San Francisco; but until the demand increases in the belt between the Mississippi and the Rocky Mountains, no great increase in tonnage can be looked for from this section.

Florida. Phosphate rock was known to exist in parts of Florida as far back as 1876, but no real start was made in mining it until 1888, when operations were started on the Peace River and about 3 000 tons were dredged and shipped to Atlanta, Ga. From this time the growth of the industry has been phenomenal. It can best be realized when we consider that 46 000 tons were mined in 1890, and twenty years later, in 1910, 2 067 507 tons were taken out. In 1911, Florida produced 79.8 per cent. of the entire production in the United States, with a value of $9 473 638. In 1911, Florida marketed 2 436 248 long tons, the greatest output of phosphate in its history up to that time. In 1912 the rock marketed fell off to 2 406 899 tons, but the actual rock mined in the state showed an increase of about 3 per cent. over that of 1911, indicating that the mines were carrying a slightly increased stock on hand over what they had in 1911.

The phosphate beds in Florida are located principally on

the west coast in Polk, De Sota, Hillsboro, Pasco, Hernando, Sumpter, Citrus, Marion, Levy, Suwanee and Columbia counties. Rock in smaller quantities is also found in some of the counties in the north and west part of the state, but at the present time these beds are not worked, as they are not extensive enough to pay for developing. The rock found in the upper belt, or in the area extending from Suwanee County to Hernando County,

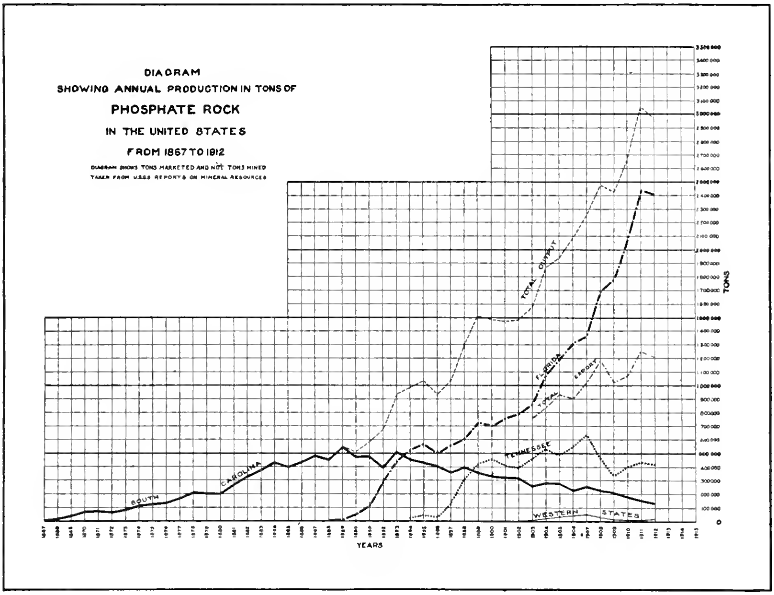

FIG. 1.

is the hard rock, while the pebble rock is found in a rather restricted area in Polk, De Sota and Hillsboro counties.

Practically all of the rock mined in the state of Florida is shipped away by water, very little being sent by rail. A large part of all the phosphate rock mined in the United States is shipped abroad. The following table shows the amount which was marketed during the past ten years and the total amount exported:

TABLE 1.

Year.	Total Tons Marketed.	Total Tons Exported.	Per Cent. of Rock Exported to that Marketed.
1903	1 581 576	785 259	49½
1904	1 874 428	842 484	45
1905	1 947 190	934 940	48
1906	2 080 957	904 214	43½
1907	2 265 343	1 018 212	47½
1908	2 386 138	1 188 411	50
1909	2 338 264	1 020 556	43
1910	2 654 988	1 083 037	41
1911	3 053 279	1 246 577	41
1912	2 973 332	1 206 520	40½

From the above table it will be noted that while the amount of rock marketed during the last decade shows a very marked increase, the percentage exported has fallen off. As the necessities of this country increase, the natural tendency will be to export less and less. Practically all of the hard rock is exported, there being very little demand for it in this country at the present time.

Very complete railroad development has taken place in the vicinity of the phosphate mines. The two great systems of railways which operate in this region have built a network of feeders into practically every place where a mine is located, and there are also a few independent lines which operate among the fields, and handle a considerable part of the tonnage.

Developing and Operating.

The development of a mine can be considered as resolving itself into several distinct stages or steps:

First. The preliminary steps, which consist of:

1. Prospecting or locating the field.
2. Acquiring the property.
3. The building of the camp or town, together with the necessary power house, pump houses, stores, office, and all the parts of the central plant for operating the mine.

Second. The operating stage, which consists of:

1. The removal of the over-burden.

2. The mining of the rock and transportation from mine to washers.

3. The washing of the rock.

4. The drying and storing.

Third and last stage. Transporting and shipping the rock to the market.

We will take up each of these steps in the order in which they occur.

Prospecting. The prospecting for phosphate rock has many of the characteristics of prospecting for the higher class ores and presents as many interesting phases. The prospector's outfit consists of the usual camp outfit for a party of from four to eight men. The particular tools which are used consist of a 3-in. pipe with driving heads and hammer and an auger for taking borings to a depth of about 35 ft.

The method of prospecting is to start the borings on a section line on the tract which is to be investigated. About five holes to a 40-acre tract are generally put down until rock is found, after which the borings are taken near enough together to determine the size and amount of the rock in that particular bed, so that a careful estimate can be made and the cost of the subsequent operations be determined with reasonable accuracy. Samples are taken from these borings and analyzed, and if they show the rock to have a commercial value and the bed to contain sufficient quantity to warrant working, the purchase of the field is negotiated.

Acquiring the Property. The acquiring of the property is a part of the early steps in the work which it is impossible to describe. Any engineer who has been engaged upon right-of-way work for either railroads or industrials will realize what it means to get control of tracts of land varying from hundreds to thousands of acres, where ownership is in the hands of such shrewd characters as the Florida farmers. Some of the larger mines, as they are now operated, have taken years to acquire, while others have been acquired in a short time. In the earlier developments most of the land was bought outright, but at the present time some land is being worked through royalties based on production.

Building Camps and Power Houses. After the field has been acquired and before any mining operations can be begun, the camp or town, together with its power plant, must be built. Nearly every mine has its own town site, with power stations, pump houses, office, stores, and living quarters for the employees. Some of these are models of what can be accomplished in the way of building suitable quarters in a virgin country; others, while furnishing a home for the employees, are not such as to attract the best of either white or colored labor.

Some of the early operators in Florida worked their mines with convict labor, and furnished only the crudest quarters for both the convicts and the higher classes of labor. This condition has now been entirely done away with and at every mine visited the quarters were found to be comfortable and in some instances better than similar accommodations provided in the far more important industries of northern states.

The power plants, which must be built before any work of mining can be started, have to be of such size and capacity as will furnish ample power for the necessary pumps, washers, driers and all the operations necessary for the work. The successful operation of the mine depends more on the power house than any other one thing, and great thought, care and ingenuity is shown in the arrangement of these plants. The power plants were found to be modern, both as to type of structure and equipment, and everywhere it was noticeable that the mine operators were making every endeavor to keep abreast if not ahead of the times. Gas engines, with their producing plants, Diesel engines, Curtis and Parsons turbines, the latest types of boilers, high-pressure pumps of all kinds, are installed in many of the power plants, and every endeavor is made to keep plants up to the highest point of efficiency.

The successful starting of a mine depends to such a great extent upon the power station and the housing of the men that a large outlay of money has to be made on the part of the promoters before any income can be had from the mine.

The water supply is one of the main things in fixing on a location for the power station and village. The country being very flat and having few suitable streams, many of the properties

depend entirely on artesian wells for their water supplies. Others have dammed up small supplies of surface water and have quite considerable ponds to draw from, and all of them conserve the water to the fullest extent, using it over and over again in the different operations. It must be remembered that all of these mines are started in practically a virgin territory where, up to the time of building the plant, nothing but lumber and turpentine operations have been carried on. There is practically no labor to be had in the country, this having to be brought in, housed and taken care of from the very first. Many of the fields are situated long distances from existing railroads, and branch lines or spur tracks have to be built to the mines before any operations can be started.

Operations.

Removal of Over-burden. With the camp, power house and other necessary buildings well under way, the actual operations of the mine can be started by the removal of the over-burden. This over-burden consists of a layer of sand, loam, etc., ranging from 6 to 30 ft. in depth, and has to be removed before the mining of the phosphate rock can be begun. This removal applies to all of the rock mined wherever found in the United States. In the pebble district land in Florida it has been found profitable to work mines where the over-burden exceeded 25 to 30 ft. in depth, and at most of the mines visited the depth seldom exceeded 15 ft. This over-burden is removed by steam shovel loading into small cars, by which it is taken to the over-burden dump and there deposited, or, as was seen in some cases, by hydraulicking and pumping the over-burden to the waste bank. The former method is the one most generally employed.

In a mine visited in South Carolina, the over-burden was removed by steam shovel and simply placed to one side, the shovel making a cut about 25 ft. in width. A second steam shovel followed, taking out the phosphate rock which had been uncovered, placing it in small cars, by which it was transported to the washers. As soon as the second shovel had passed, the first or over-burden shovel was brought back and a second 25-ft. cut made, depositing the over-burden in the trench or cut made

by the removal of the phosphate rock, the second shovel again following and removing the rock as in the first cut; thus a series of cuts about 25 ft. wide was made over the entire field.

In a section visited in Florida, the over-burden was being excavated by steam shovel and the disposal by cars was used to fill an abandoned mine from which the phosphate rock had entirely been removed. In still other sections the over-burden was placed on land which had been prospected and no rock found, where the dumps in many cases form small hills, which in that level country can be seen for long distances. The hydraulic method is explained in the following in describing the methods of mining pebble rock.

FIG. 2. A PHOSPHATE MINE.

Mining of Pebble Rock. After the over-burden is removed, the actual work of mining the rock is begun. Pebble rock is found in beds varying from 6 to 15 ft. in thickness, and, as its name implies, consists of a conglomerate of small stones or pebbles about the size of pease. Cohesion is given the mass by the admixture of sand and clay, and not infrequently sharks' teeth and the bones of larger animals are found.

At every mine visited, the pebble was found lying on top of a bed of very hard white clay, commonly called " bed rock," this bed being hard enough to allow the hydraulic guns to sweep

the pebble rock free, leaving a comparatively smooth bottom after it had been mined.

The mining of the pebble rock is done exclusively by hydraulicking, the hydraulic guns working at a nozzle pressure of about 160 lb. The pumps supplying the guns are, in most cases, of the duplex compound horizontal type, the steam for their operation being furnished by boilers which are independent of any part of the power house requirements. Booster pumps of two and three stages, operated by direct connected motors, are installed to insure suitable pressure for operation. The pressure at the pump is about 200 lb. The guns are worked so as to loosen up and tear down the face of the phosphate rock, which, after being loosened, is swept by the same guns into a sump. The sumps are holes 6 to 10 ft. in diameter and a few feet deep, from which the loosened material and water is pumped by means of centrifugal pumps to the washers.

The pumps used for transporting the rock from sump to washer are 8-in. or 10-in., single stage, centrifugal type, and the pipe lines through which the material passes are often of very considerable length. The pumps are motor driven, the power being supplied from the main power house to motors generally mounted on the same shaft, the same as for the booster pumps previously mentioned. Where the line is too long for one pump to force the material from sump to washer, booster pumps are installed on the line. The life of a pump used for transporting rock is very short, the blades frequently wearing out in three months and the entire life of a casing often being less than a year. These pumps and motors are placed in small houses for protection and, as they have to be moved frequently, they are built on skids so that they can be readily transported from one place to another in the mines.

The cost of hydraulic mining and transporting of the rock is very low, there being very little actual labor required. With an expert operator on the gun, the amount of rock actually swept to the sump averages about 15 per cent. of the water used. The sump pumps are of such size that they will just about take care of the amount of water which is coming from the guns, including the solid material washed in. It is very seldom that one sees

any water wasted, the amount from the guns and amount used by the pumps being practically identical. The suction for the sump pump is rigged so that it can be readily raised and lowered to facilitate clearing the pumps, which frequently become clogged.

Washing the Rock. The pipe line from the mine sump delivers the rock and its débris directly to the washers, where the clay, sand and other impurities are taken out.

The washer consists first of a revolving sheet-iron screen with random punched holes about an inch and a half wide by two to four inches long. This screen is about 8 ft. long and 30 in. in diameter, and is set with a pitch of about one to six. The rock from the pipe line is pumped into one end of this screen and, owing to the pitch and to the fact that the clay balls are lighter than the rock, the rock passes through the punched holes while the clay balls roll down the inside of the screen and pass out at the open end. The phosphate rock drops into troughs containing revolving agitators, or logs, which agitate the rock and free it from the sand and other foreign substances. From the agitators the rock is passed over a series of shaking screens where the sand is finally separated from the rock. The rock from the last screen passes to the boot of an elevator, where it is picked up and placed in the hopper ready for transportation to the driers.

After the rock leaves the washers it is known as "wet rock," to differentiate between the wet or undried rock and "dry rock," as it is known when ready for shipment. The "wet rock" is usually transferred from the bins to the driers by cars on account of the washers being situated generally near the mines, while the driers are located at some point adjacent to the big dry bins and railroad tracks. At some of the mines large piles of "wet rock" were stored near the driers, for emergency uses in case of a breakdown at the mines. In one case a hydraulic gun was installed at this emergency pile, the "wet rock" being swept to a sump and pumped by a centrifugal pump direct to the hopper leading to the driers, but as a usual thing this "wet rock" is handled by steam shovel and cars.

Drying the Rock. At the driers the wet rock is first elevated to a hopper from which it is fed directly into cylindrical, rotary

driers about 40 ft. long and 5 ft. in diameter. These driers are set at an angle of about 12 degrees from the horizontal so that the rock passes through them from the upper to the lower end by gravity. Inside of the cylinders a series of baffles is so arranged that the rock is thoroughly stirred while passing through them. The furnaces are located at the low end and are usually equipped with oil burners. As the rock is fed into the upper end of the drier in a very wet condition, it strikes the cooler surfaces first, the heat increasing as it approaches the furnace.

At the point where the rock leaves the drier the heat is so intense that many of the pebbles are exploded with a noise not unlike the popping of corn. As the hot rock leaves the drier it is dropped upon a sheet steel apron conveyor, which transfers it to the top of the dry bin. Here it is either taken by apron conveyors or by small cars and dumped in whatever portion of the bin it may be wanted. At some of the plants visited it can be said that from the time the rock is washed out of its bed by the hydraulic guns to the time when it goes into the dry bin, it is not touched by any but mechanical appliances.

Transporting and Shipping.

As both the hard rock and land pebble mines lie on the west coast of Florida, the matter of transporting the rock from the mines to the nearest port has been a matter of a great deal of competition between the two principal railroads operating in that section. Tampa was formerly practically the only port on the west coast of Florida, and both the Atlantic Coast Line and the Seaboard Railroad have made every effort to get the best of facilities there, as well as to get branch lines into every part of the mining districts. A glance at a map of the west coast of Florida will show that one or the other, and perhaps both of these lines are in practically every district where the rock is found. The transporting of something over 2 000 000 tons a year is a question in which they are vitally interested, and every endeavor is made to give the best possible service.

One of the problems which the railroads had to solve was the building of a car which would convey the rock from the dry bin to destination without danger of dampness or wetting. The

best cars so far built for this traffic are all-steel cars with four hinged hatches and solid top. These cars are designed to carry thirty tons of rock and keep it dry during transit. As the car can be loaded direct from the chutes in the dry bin and unloaded by the hopper in the bottom direct to the elevator boot, all hand labor is obviated.

The transportation of the rock from the mines to the factory or the port where it is to be loaded for shipment concludes the mining operations. The handling of the rock at the various ports is very much the same as the handling of grain from elevator to vessel. Much of the rock on its arrival at a port is placed in large storage bins holding from 15 000 to 25 000 tons, and from these it is transferred to the vessels by means of belt conveyors. At some of the ports visited vessels of from 5 000 to 6 000 tons were being loaded in about ten hours. While this does not compare with the speed of loading grain or ore at ports on the Great Lakes, it must be remembered that the production is not enough to warrant the elaborate and expensive facilities which are necessary where material is handled as it is on our Great Lakes.

Conclusions.

The life of the present phosphate beds is a question that is agitating many of the operators and scientists in the southern fields to-day. As has already been shown, the South Carolina fields will be exhausted within a few years. The Tennessee, the Arkansas, and the fields so far discovered in the West are too far from the coast to get the advantage of the cheap freight rates which the Florida and South Carolina fields enjoy. In Florida the mining of river pebble has not been carried on for the past four years. The extent of the hard-rock fields is now known with a fair degree of accuracy, and it is possible to make an approximation of the amount still remaining of this class of rock. The pebble rock, or Bone Valley, formation, has so far been limited to the rather small extent of territory in Polk and Hillsboro counties, but prospectors have been working for the past two years in Manatee, DeSota and Lee counties, but with results known only to themselves. In 1911 a new deposit was

discovered to the southwest of the Bone Valley District in Hillsboro County, and no one can foretell how much more of this pebble rock will be discovered in southern Florida.

In the Second Annual Report of the Florida State Geological Survey, 1909, Mr. G. H. Sellard, state geologist, makes the following statement:

> "With the extension of the agriculture necessary to support increased population, together with the progressive exhaustion of the new and naturally rich soils, there arises increased demands upon the phosphate supply. At the present time this demand is chiefly coming from the older countries of Europe, and the phosphate now produced is largely exported. The time is not far distant, however, when as equally strong demand will come from the exhausted soils of our own country."

Table 1 shows how the percentage of rock exported has already decreased in the last five years from something under 50 per cent. to about 40 per cent., proving the correctness of Mr. Sellard's judgment that the demand at home would begin as soon as the soil was exhausted.

With a view to conserving as far as possible the remaining supply in the state of Florida, all the state lands within the phosphate section were withdrawn from sale in 1909 until such time as they should be properly classified. In the same year the President withdrew from entry 27 400 acres of government land in the phosphate section. In 1912 a part of this government land was ordered returned for entry as examination showed there was practically no phosphate upon it.

It is the opinion of the writer that as far as the present or coming generation is concerned there need be no anxiety felt about the present supply of phosphate rock. There is rock enough in Florida to supply the needs of the potato grower of Maine and Michigan, the truck farmer of Long Island and New Jersey, the tobacco raiser of Virginia or the cotton planter of the South for a great many years, and that, too, without withdrawing our present very large shipments to supply the needs of the German and Austrian gardener. The writer believes that undue restrictions in either the mining or the exporting of phosphate rock are not necessary at the present time, and that the increased demand in years to come will be fully met by the development of present known fields in the South and West and the future discovery of fields hitherto unsuspected.

Vol. 1 DECEMBER, 1914 No. 10

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PAPERS AND DISCUSSIONS

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THE HYDRO-ELECTRIC POWER PLANT AT THE WACHUSETT DAM, CLINTON, MASS.

By B. C. Thayer and E. R. B. Allardice, Members Boston Society of Civil Engineers.

(To be presented December 16, 1914.)

Preface.

In these days when the conservation of our natural resources attracts the attention of men in all walks of life and makes exacting demands upon the abilities of the engineer, the description of the design, construction and operation of the first hydro-electric power plant using the waters of a domestic supply for the development of electrical energy may be of interest to the members of this Society. The development to be described is, so far as we have been able to ascertain, the first of its kind in the history of the world.

Preliminary.

The Massachusetts Legislature of 1893 directed the State Board of Health to investigate and report upon the question of a water supply for the city of Boston and its suburbs within a radius of ten miles. This report resulted in the Legislature of 1895 passing an act directing the governor to appoint three

Note. This paper is issued in advance of the date set for its presentation. Discussion is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before February 10, 1915, for publication in a subsequent number of the Journal.

water commissioners who should constitute the Metropolitan Water Board, which should construct, maintain and operate a system of water works substantially as recommended by the State Board of Health. As a part of the water works recommended, there was constructed upon the south branch of the Nashua River, about one mile above the town of Clinton, a large dam, storage reservoir, aqueduct and power station. This

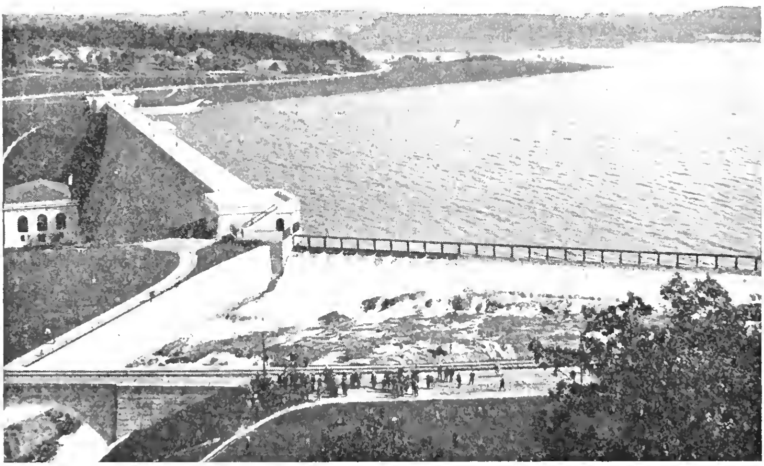


FIG. 1. WACHUSETT DAM.

act authorized the Board to utilize the fall of water at any dam under its charge, and thereby produce power or electricity, and to transmit such power or electricity by pipes, wires or other suitable means, and to sell the same, or the right to use such water, by written or other contract, to run for a term not exceeding fifteen years. Thus it is seen that the early plans for the development of the Nashua River watershed as a domestic water supply included conserving the energy which could be developed from the fall of the water at the dam before it entered the aqueduct.

The Wachusett Dam is a gravity type structure 944 ft. long, including abutments at each end, crossing the valley of the river, with its top 20 ft. above high-water level in the reservoir. Extending from the northwesterly end is a waste weir 452 ft. long, over which the flood waters are discharged into a channel excavated in rock, 1 150 ft. long and falling 107 ft. into the river below. The main dam is composed of granite rubble masonry quarried about a mile from the dam, with a facing, where exposed, of ashlar quarried in Chelmsford, Mass. The height at the point of deepest excavation is 207 ft. and the maximum thickness is about 185 ft. The thickness at the finished ground level below is 81.5 ft. and under the projecting cornice at the top 22.5 ft.

The Wachusett Reservoir has a watershed area of 108.84 sq. miles. It is 8.41 miles long, with a maximum width of 2 miles, an area of 4 150 acres or 6.48 sq. miles, and a capacity of 64 968 000 000 gals. The maximum depth of water is 129 ft., the average depth being 48 ft.

The first two miles of the Wachusett Aqueduct which conveys water from the Wachusett Reservoir is a rock tunnel, followed by seven miles of masonry aqueduct, including a bridge over the Assabet River, and three miles of open channel. The tunnel section has a fall of 1 ft. in 5 000, is lined for about one half of its length with brickwork 12 in. thick, and where lined is 12 ft. 2 in. wide and 10 ft. 10 in. high. The masonry aqueduct has a fall of 1 ft. in 2 500, and is 11 ft. 6 in. wide and 10 ft. 6 in. high. The open channel is 20 ft. wide on the bottom and has side slopes of three horizontal to one vertical. This structure, which serves as the tailrace of the power plant, has a capacity of 360 000 000 gals. per day.

The first contract, which was for the construction of the aqueduct, was let February 14, 1896; water was first turned from the Nashua River into the aqueduct on March 7, 1898; the Wachusett Dam and Reservoir were substantially completed in 1906, and the reservoir was for the first time filled to high-water mark on May 10, 1908.

Legislation.

The contract for the construction of the Wachusett Dam, which included the foundations of the power station, was let October 1, 1900, and that for the superstructure of the power station, March 18, 1904. This building was completed, ready for the installation of machinery, on December 22, 1904, but owing to laws relative to the taxation of the Board's property, actual installation of the hydro-electric plant was not begun until February, 1911. The Legislature of 1902 authorized the town of Clinton to tax all property held by the Metropolitan Water and Sewerage Board in the town of Clinton, outside of the dam and dikes, used in the generation or sale of electricity for power or for manufacturing purposes.

Only a comparatively low price could reasonably be expected for the power developed, for two reasons: First, it being a domestic supply the demands for water would be varying, causing considerable fluctuation in the amount of power developed; and, second, repairs and alterations to the various structures in the extensive water supply system might cause more or less protracted interruptions. For these reasons, and the very great value of the property subject to taxation under the act of 1902, the Board felt that the legislature should determine upon a fixed valuation of the amount of its property subject to taxation in the town of Clinton.

Accordingly, on May 13, 1910, there was passed the following act:

"*Section 1.* The property held by the Metropolitan Water and Sewerage Board, or its successors, in the town of Clinton which may be subject to taxation under the provisions of section two of chapter four hundred and ninety-eight of the acts of the year nineteen hundred and six shall be assessed on a valuation of one hundred and twenty-five thousand dollars in any year in which any power is generated and sold."

"*Section 11.* In the sale or disposal of electricity generated in the town of Clinton for power or manufacturing purposes under the provisions of section three of chapter four hundred and eighty-eight of the acts of the year eighteen hundred and ninety-five preference shall be given to persons or corporations proposing to use all of such electricity in the town of Clinton; *Provided*, that there are responsible persons or corporations so proposing to use all the electricity in said town who shall offer to purchase the same on

terms as advantageous as shall be offered by others not so proposing to use the same; and the said Board shall, at least ten days before making a contract for the sale of such electricity, cause to be printed in some newspaper published in said town a request for proposals for the purchase of electricity to be generated and sold by said Board."

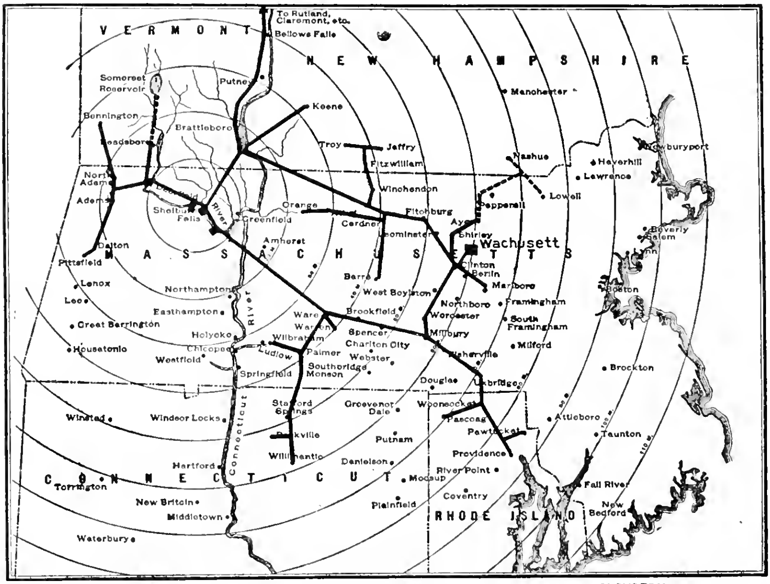
Previous to the passage of this act, however, the Clinton Board of Trade investigated very thoroughly the advisability and possibility of the town's taking over the local electric light and gas plant and using it in connection with the municipal purchase and sale of metropolitan power. This investigation showed that it was not a good financial proposition for the town to undertake because of the inflated valuation placed on the electric light and gas plant and also because of the lack of a guaranteed continuous service from the metropolitan power station. After all this delay and consequent loss of revenue to both the state and the town, the taxable value of the power plant was agreed on at $125 000 by all parties concerned and was so fixed by the legislature. This sum is substantially the cost of the hydro-electric machinery, foundations, floor and fixtures placed in the power station building since its completion in 1904.

Preliminary estimates of the amount of power available based on an average daily flow of 100 000 000 gals. of water, together with a rough canvass of the probable market for the sale of the energy, indicated that with the taxable value fixed at $125 000 a fair profit could be realized even at the necessarily low selling rate expected.

Sale of Energy.

The Board now proceeded, in accordance with the act of 1910, to secure a market for the energy which was necessary before the plant could be designed. A canvass of the probable customers resulted in a five-year contract being made September 14, 1910, with the Connecticut River Transmission Company, a company distributing 3-phase, 60-cycle alternating current generated at several plants on the Connecticut and Deerfield rivers, and furnishing energy to the Lancaster Mills, Clinton, over a 13 800-volt transmission line passing within a few hundred feet of the Wachusett Dam. This contract reserved to the Lancaster

Mills the right to the power to be developed at the Wachusett Dam at all times when required, thus fulfilling that part of the Act of 1910 which protected the industries of the town of Clinton. This clause was made possible through the fact that the then president of the Lancaster Mills was a large stockholder and director of the Connecticut River Transmission



Power Stations
Existing Lines
Proposed Lines

MAP SHOWING TRANSMISSION LINES OF NEW ENGLAND POWER COMPANIES' SYSTEM AND CONNECTING LINES

Fig. 2.

Company, and therefore directly interested in the welfare of both concerns.

The contract was of particular advantage to both the company and the Board because the company had other large hydro-electric generating stations which could be run at maximum capacity during the seasons of high-water when the draft upon the Wachusett Reservoir would be at a minimum and because the Metropolitan Power Station could be run at its maximum capacity during the dry season when the demand upon this source of supply would be largest and when the streams

controlled by the Company would be lowest. During the three years and over that the contract has been operative, these conditions have been even more pronounced than was anticipated.

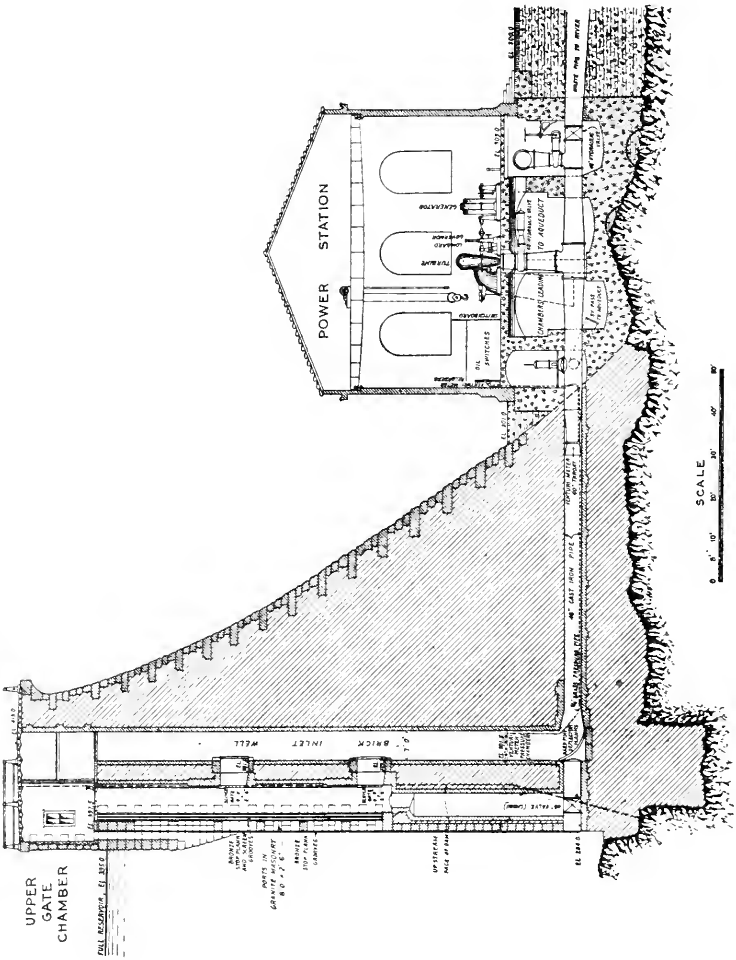
Description of Plant.

The market for the power and consequently the kind of energy to be developed being fixed, it was deemed desirable that a high voltage plant be installed in order to connect directly with the 13 800-volt transmission line of the Connecticut River Transmission Company.

The plant as finally designed and constructed consists of four, 1 200 h.p., horizontal-shaft turbines of the scroll case type, working under a head of from 80 to 100 ft., each equipped with a type "Q" Lombard governor and directly connected to a 1 000 k.v.a. alternating-current generator; one 100 h.p. Holyoke horizontal-shaft turbine with a cylinder gate, and one 110 h.p. Smith horizontal-shaft turbine with wicket gates, each directly connected to a 60 k.w. 125-volt direct-current generator used for excitation; an eleven-panel switchboard, together with the necessary instruments, meters, transformers, etc.; a 10 h.p. motor driving a 6-in. Lawrence submerged sump-pump; a 5 h.p. motor for operating 6 ft. x $2\frac{1}{2}$ ft. sluice gates; a 6 h.p. motor for handling stop planks, screens and gates in the upper gate chamber; a hand-operated 12–20-ton traveling crane; and a double transmission line from the switchboard to the lines of the Connecticut River Company, consisting of 815 ft. of underground and 600 ft. of overhead with lightning arresters in a suitable building at the junction of the two portions.

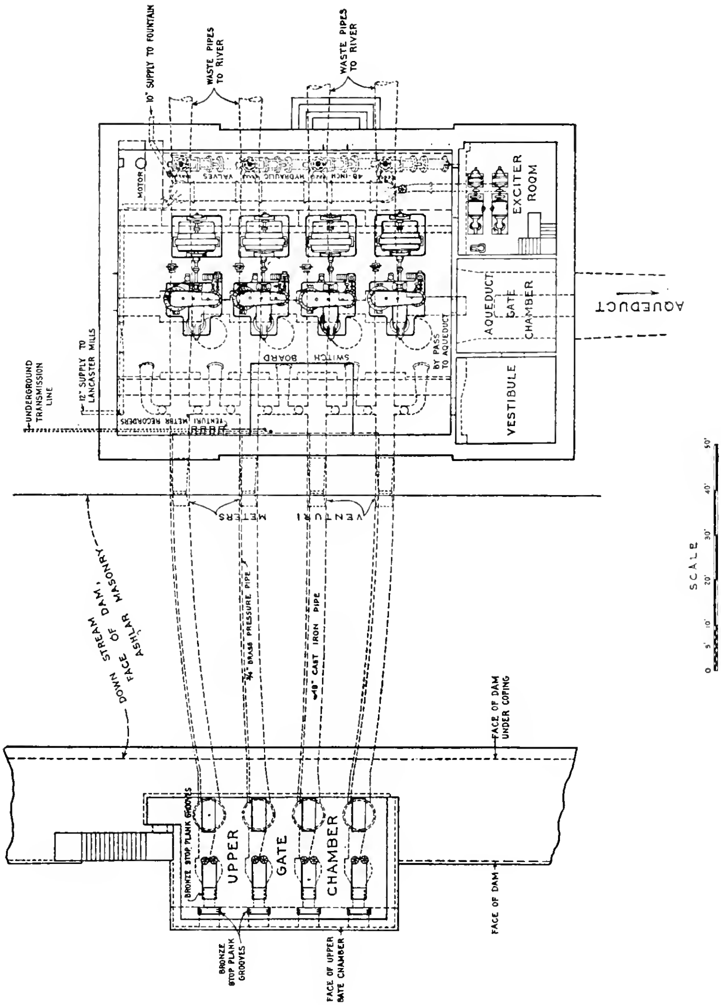
Power Station.

The building is 104 ft. 6 in. long, 74 ft. wide, and the ridge of the roof is about 59 ft. above the ground. The exterior walls are of fine-pointed Chelmsford granite. The generator room, which occupies the larger part of the building, is 74 ft. 1 in. long by 64 ft. wide, with a height from floor to ceiling of about 39 ft. There are also eight smaller rooms and a large storage room. Three of the smaller rooms are used as office quarters for the



WACHUSETT DAM — SECTION THROUGH GATE CHAMBERS AND POWER STATION

FIG. 3.



WACHUSETT DAM — PLAN OF GATE CHAMBER AND POWER STATION

FIG. 4.

maintenance force of the Wachusett Department, while the others are devoted to various uses in connection with the power plant and the control of water entering the aqueduct. The interior walls are faced with red-face brick with brownstone trimmings, and the roof is covered with Conosera Spanish roof tiles.

This building was designed for the threefold purpose of serving as a gate chamber for the control of water flowing into both the Wachusett Aqueduct and into the Nashua River below the dam, as a power station for the installation of the hydro-electric plant, and for the office quarters. The building is an expensive one for a power plant, but it was thought proper to make it large enough to harmonize with the massive dam that it adjoined and at the same time restrict the size of the generator room to the lowest possible dimension necessary for proper construction and operation.

Foundation and Conduits.

The interior walls of the wells, the foundations of the power plant and the floor of the power station building were not completed when the building was constructed. To do this work required placing about 445 cu. yds. of 1 : $2\frac{1}{2}$: $4\frac{1}{2}$ mass concrete. The chamber beneath the generator room into which the water passes from the turbines is 34 ft. x 74 ft. 1 in., with piers about midway supporting arches forming the floor. The primary arches which span this chamber from walls to piers have spans of 14.5 ft. and 15.5 ft. with a thickness of 6 ft. at the springing line and 3.25 ft. at the crown of the arch. These primary arches, of which there are five, are 6 ft. wide and 15 ft. between centers. Secondary arches, springing at right angles to the longitudinal axes of the primaries, complete the floor area over this chamber. There are four of these, each having a span of 9 ft., length of 34 ft., thickness 3.25 ft. at springing line and 2 ft. at crown of arch. The concrete in each one of these arches was all placed at one time. After setting an arch form the conduits were hung in place, all anchor bolts set, and the necessary forms for penstock and draft tube built before the concrete was placed. The primary arches were built first, then the

penstock lines assembled, draft tubes placed temporarily below the floor and the secondary arches built last. To complete the floor of the generator room, small concrete arches were constructed over the gate chambers at either side of the chamber leading to the aqueduct. The whole floor was finished with red American Promenade floor tile. This work was done by the maintenance force of the Wachusett Department.

Embedded in the concrete are "Sheraduct" iron conduits varying in size from $\frac{1}{2}$ in. to 3 in., which contain the lead-covered cables connecting generators and switchboard, and the lighting, telephone, power and bell wires. These conduits were furnished and laid under contract with the M. B. Foster Electric Co., of Boston, Mass.

Main Turbines.

As previously stated, the plant contains four scroll-case turbines guaranteed to deliver 1 200 h.p. when operating under a 90-ft. head, at a speed of 400 rev. per min. Each contains a 30-in. S. Morgan Smith Company's type "K" runner, after the Francis type, made of a solid bronze casting pressed on to the turbine shaft. The specifications called for the runner to be able to withstand safely the stresses due to opening the gates full with the shaft blocked and to the runaway speed of the runners under the maximum head. They also specified that the capacity of the runner be not less than 160 nor more than 170 cu. ft. per sec. with the regulating gates wide open, the speed 400 rev. per min. and the net head 90 ft. The scroll case, whose inlet and outlet are 48 in. in diameter, was shop tested under a pressure of 100 lbs. per sq. in. Together with the discharge elbow and both bearings, it is mounted on a cast-iron base plate, which is concreted in and rigidly held by large anchor bolts. In the scroll case there are stationary guides cast as an integral part of the case, inside of which are the wicket gates. These gates together with their stems are drop forged in one piece. The stems on one end of the gates extend through the scroll case and operate in bronze-lined journals. They are operated by cast-steel lever arms connected to the cast-steel external shifting ring by forged steel links, with an eccentric

pin for individual adjustment of each gate. The gates are controlled by a type "Q" 7½-in. by 16-in. Lombard governor with motor control on the switchboard.

The turbine shaft, which is made of best quality forged steel, is supported by two main bearings. The bearing next to the generator is a self-aligning, ring-oiling bearing, while the remote bearing is a cantilever type, ring-oiled, water-cooled, and is rigidly supported by a heavily ribbed bracket on the dis-

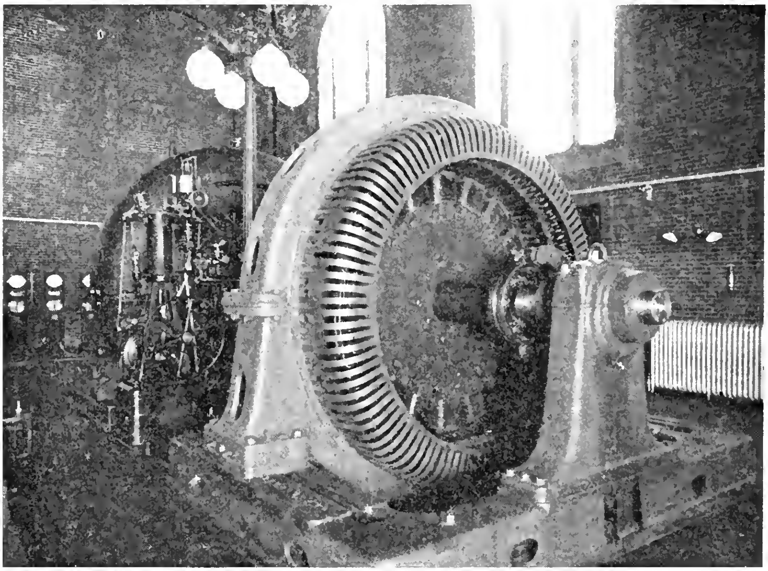


FIG. 5. 1 000 K.V.A. GENERATOR AND 1 250 H.P. TURBINE.

charge end of the elbow. On the rear end of this bearing there is a cast-iron hood containing a ball thrust bearing designed to take care of the end thrust of the runner. This bearing consists of eight 2½-in. steel balls running in a case-hardened steel race. The space over the top of the runner is drained by means of pipes in order to reduce the pressure on top of the runner, as a large percentage of the end thrust comes from the pressure in this chamber. The thrust bearing and both main bearings are lubricated by a water-cooled circulating oil system operated by a small pump belted to the main shaft.

In view of the fact that this was the first time that an end thrust bearing of this type had been used on these turbines, some doubt was felt as to their reliability. Consequently, to relieve the wear on these bearings, the main generator armatures were set about $\frac{3}{8}$ in. out of their magnetic field centers away

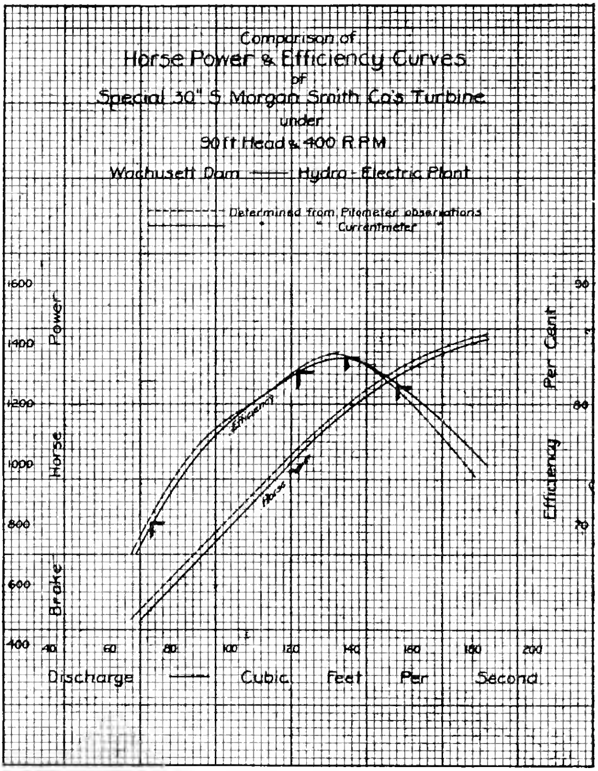


FIG. 6.

from the turbine. The results obtained by doing this have been more satisfactory than was at first anticipated, for during more than three years of operation not a single replacement of parts or repairs has been made, and although the ball races show some signs of wear, to all appearances they are good for several years to come.

Main Generators.

Directly connected to the turbines just described are the four main generators rated at 1 000 k.v.a., 3-phase, 60-cycle, 13 800 volts, 400 rev. per min. There is nothing unusual in either the design or characteristics of these generators. The

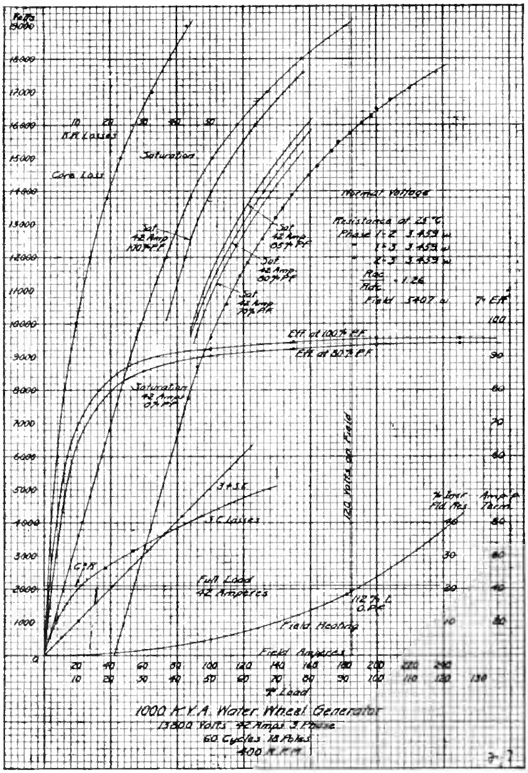


FIG. 7.

armature coils are form wound with square wire, insulated before being placed in armature core, thoroughly braced, held in place by wedges and connected in star.

The field poles are dovetailed to the spider, and are provided with dampers to prevent shunting. The field coils are wound with copper strap, wound edgeways and were subjected

to a puncture test of 1 500 volts. The revolving element complete weighs 10 tons, and is supported by two self-aligning, babbitt-lined, ring-oiled bearings. These generators were all tested at the factory in accordance with the "Standardization Rules of the American Institute of Electrical Engineers" and curves plotted of the results obtained as shown in Fig. 7.

The specifications called for an overspeed test of 800 rev. per min., with full field current, but allowing the armature winding to be split electrically and each part grounded to prevent abnormal rise in voltage; but in running this test the armature winding was not split but connected as for normal operation, which resulted in their obtaining a terminal voltage of 35 900, or nearly three times the normal operating voltage, without any sign of breakdown. Another severe test that was made was, with the generator running at normal speed and voltage and carrying 25 per cent. overload, a dead short circuit was applied at the terminal without the protection of breakers or relays. After witnessing these tests the engineer who represented the Board expressed himself as being fully satisfied as to the ability of these generators to withstand short circuits or excessive voltage.

Exciter Turbines and Generators.

There are two horizontal-shaft, hydraulic turbines, used for the exciter units. One is a Smith turbine capable of developing 110 h.p. at a speed of 1 000 rev. per min. under a working head of 90 ft., and is of the wicket-gate type with a $11\frac{1}{2}$-in. Swain-type bronze runner. This turbine is fitted with a type "F" Lombard governor, while the gate-operating mechanism is of the internal-link type. The other is a Holyoke turbine capable of developing 100 h.p. at a speed of 1 100 rev. per min. under a working head of 90 ft., and is of the cylinder-gate type with a 9-in. runner. This turbine is fitted with a mechanical governor. Each of these turbines is directly connected to a 60 kw. direct-current, 125-volt, shunt-wound interpole generator used for exciters, either of which is capable of furnishing excitation to all four main generators.

Penstock Lines.

Each turbine has an individual penstock line from the reservoir to the wheel, consisting of a masonry chamber built in the dam, which is provided with screens, stop planks and sluice gates; a vertical well 7 ft. in diameter extending to a depth of 111 ft. below full reservoir level; a 48-in. cast-iron pipe extending horizontally 94 ft. further; a 60-in. tee; a 60-in. to 48-in. reducing curved riser, 48-in. gate and 48-in. filling piece terminating at the flange connection of the scroll case.

The 48-in. gate is operated by water pressure from the reservoir. The pressure chamber has an inside diameter of 24 in. and the gate is equipped with a 4-in. hand-operated by-pass valve. Connected with each line there are two 24-in. branches controlled by 24-in. hydraulic operated gates through which water can be passed directly into the aqueduct without passing through the wheels.

Tailrace.

The draft tubes of the turbines are located in one of two large wells beneath the floor of the generating room. These wells connect directly with the Wachusett Aqueduct which has a carrying capacity of 360 000 000 gals. per day and is the tailrace of the plant.

Switchboard.

The switchboard consists of eleven panels of Munson slate with black marine finish, for the control of the apparatus as follows. From left to right: Tirrell regulator panel, two exciter panels, four main generator panels, total load panel, line panel with instruments for reading the voltage and frequency of the feeder lines, a panel designed for the control of motors to be installed at some future time on the sluice gates in upper gate chamber, and a blank panel which is now used for the instruments on the sewage Pumping Station line. The switchboard is set 12 ft. from the rear wall of the power plant and is supported by a framework made up of $1\frac{1}{4}$-in. pipe extending from the switchboard to the wall on which is mounted the current and

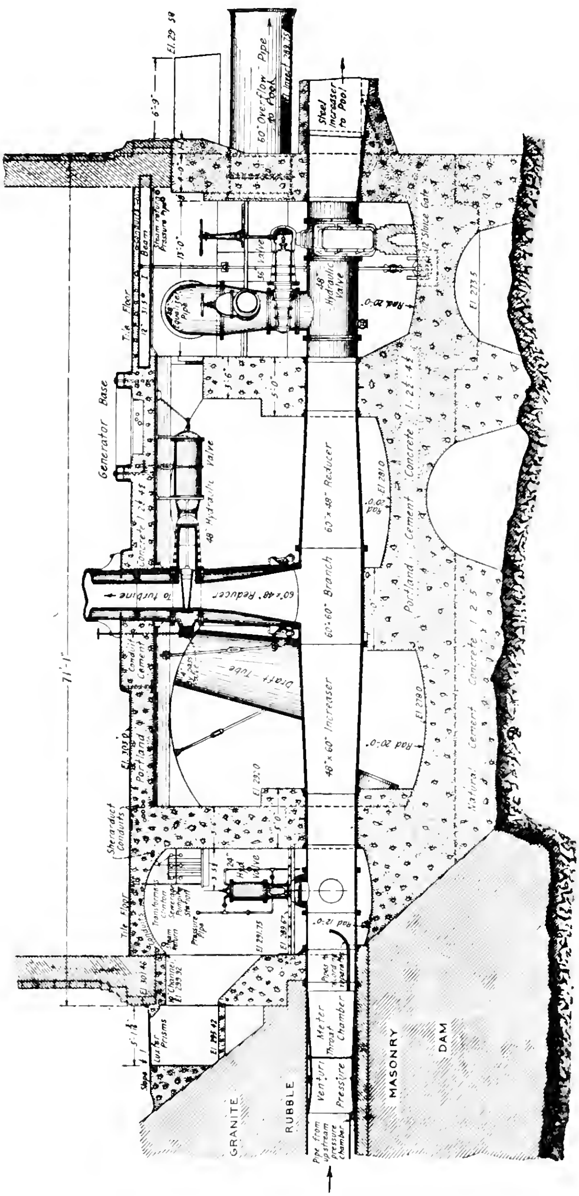


FIG. 8. SECTION THROUGH GATE CHAMBER.

potential transformers, oil and disconnecting switches, high-tension bus, etc. The four oil switches for the main generators and the two oil circuit breakers for the outgoing lines are encased in separate asbestos board compartments with removable doors for inspection or repairs. Used in connection with each of the circuit breakers are two single-phase overload inverse time relays.

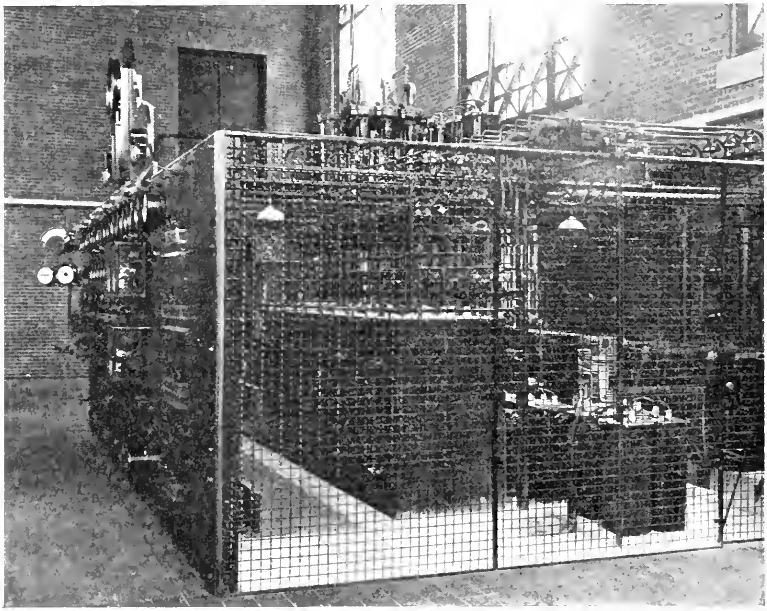


FIG. 9. SWITCHBOARD.

On the total load panel are three graphic recording meters for the voltage, power factor and kw. output of the station, and the integrating watt-hour meters for the station output and the energy used in and about the station. Three 25 kw. oil-insulated, self-cooled transformers are so connected to the high-tension bus through expulsive fuses that polyphase energy is available for lights or power at all times whether the station is in operation or not, energy being taken from the Connecticut River Company's lines when the station is shut down.

Transmission Line.

From the switchboard of the power plant the transmission line is carried underground a distance of about 815 ft. by means of two lead-covered cables drawn through two lines of $3\frac{1}{2}$-in. Orangeburg fiber conduit laid in Portland cement concrete. Three concrete manholes were constructed for convenience in pulling in the cables, and as one section of the line runs up a steep incline with a 2 to 1 slope, two hand holes were built about 75 ft. apart, and the cables anchored in each of them by means of strain clamps. The cables were furnished and installed by the Standard Underground Cable Company, of Pittsburg, Pa., and are made up of three paper insulated conductors, each composed of nineteen strands of copper wire having a conductivity equivalent to a solid No. 0, B. & S. gage wire. Before shipment from the factory the cables were subjected to a puncture test of 30 000 volts, and were guaranteed for five years.

At the end of the underground line a building 20 ft. long by 14 ft. wide was constructed of concrete with a roof of red Imperial Spanish tile. In this building are installed the three-phase electrolytic lightning arresters with the necessary choke coils, horn gaps, etc. The underground cables are connected direct to the choke coils, then to the overhead lines through disconnecting switches. Since the plant has been in operation additional disconnecting switches have been installed so that either cable may be connected to either of the overhead circuits or the two cables put in parallel to feed one of the overhead lines. From the lightning arrester station to the lines of the Connecticut River Transmission Company, a distance of about 600 ft., the transmission line consists of six No. 1 stranded bare copper wires strung on 35-ft. poles, connection to the Connecticut River Transmission Company's lines being made at the junction tower through disconnecting switches.

Progress of Construction.

The contract for the sale of the energy to be developed called for the delivery of a portion of such energy as soon after

July 1 as possible. The 12-20-ton crane, for use in connection with the erection and maintenance of the plant, was installed early in February, and concrete work was begun in the latter part of that month. The large penstock castings arrived in March and the work of installing them began immediately, being carried on with two gangs working day and night. During April, May, June and July the penstock valves, Venturi meters, turbines, generators and switchboard were installed and the transmission line and lightning arrester station were constructed. The plant was first put into commercial service August 10, 1911.

From the construction standpoint there were a few conditions peculiar to this job which may be of interest, foremost among which was the necessity of conducting operations so as to be able to furnish water to the metropolitan district whenever necessary and the consequent necessity of securing all concrete forms and falsework against the action of the water. As the room in which the plant was being installed was but 74 ft. x 64 ft., and as there were working together in this confined space, the forces of three different contractors and one day-labor force, aggregating as a rule about 38 men, it will be readily seen that considerable attention had to be given to laying out the work for these various forces in order to keep progress up to its maximum without friction among the men.

The cost of the plant, complete, was as follows:

4 1 200-h.p. turbines, 4 1 000-k.v.a. generators, 1 110-h.p. exciter turbine, 2 exciter generators, 4 Lombard governors and electric equipment furnished and installed by S. Morgan Smith Co. and Westinghouse Electric and Manufacturing Co.	$69 639.62
Lombard governor on exciter turbine	935.12
1 100-h.p. Holyoke exciter turbine	900.00
Lightning arrester station	2 348.44
Underground transmission line	2 693.47
Overhead transmission line	949.30
Labor and materials furnished in connection with the wiring in the building (Shorarduct pipe, etc.),	2 022.98

Penstock pipes and valves:		
4 48-in. valves	$5 068.00	
Special castings (about 113 tons)	7 474.40	
Installing castings and valves	2 832.59	
		15 374.99
4 Venturi meters and installation of same		6 211.94
Floor of power station, including concrete foundation for turbines and generators		7 883.29
Traveling crane		2 500.00
Miscellaneous labor and materials		3 020.27
Engineering		9 521.06
Total		$124 000.48

Measurement of Water.

For the purpose of accurately measuring the quantity of water used by each turbine and furnished to the Metropolitan District, there was installed in each penstock line a very special 84-in. by 40-in. Venturi meter, furnished by the Builders Iron Foundry of Providence, R. I. Each meter comprises an upstream pressure-chamber, consisting of a ring of 3-in. brass pipe set in a recess cut in the brick wall of the 7-ft. diameter vertical well, and a throat section 40 in. in diameter, 10 ft. 4 in. long, made in two sections for convenience in inserting in the 48-in. pipe. These sections were securely riveted to the inside of the 48-in. pipe, the end closures being made with special molded lead joints. The distance from the pressure-chamber to the throat of the meter is about 90 ft., including a difference in elevation of $15\frac{1}{2}$ ft. Water is admitted to the upstream pressure-chamber through twelve $\frac{1}{2}$-in. diameter openings in brass plates set flush with and true to the curvature of the walls of the well. The throat section has an annular pressure-chamber and is lined with bronze accurately bored to the standard Venturi curves. There are thirteen $\frac{5}{16}$-in. openings through the bronze lining into the annular pressure-chamber. The pressures from both the upstream and throat pressure-chambers are transmitted to the recording instruments in the generator room through brass pipes $\frac{3}{4}$-in. in diameter. The recording instruments, which are the standard type "M," have three dials; one indicating the rate of flow in million gallons per day, one

for continuously recording this rate upon a chart, and one for registering the total flow through the meter. Owing to the very unusual conditions under which these meters were to operate and the consequent special types of construction, the standard formula for computing the flow was not applicable, and it was therefore necessary to calibrate accurately these meters after they were installed. This calibration was made by the engineers of the Metropolitan Water and Sewerage Board and was as follows:

A gaging station is located in the Wachusett Aqueduct about 2½ miles below the power station, and at the lower end of a tangent 1 300 ft. long, where current meter measurements of the flow of water can be accurately made. For measuring the velocity of water flowing in the aqueduct, two Fteley and Stearns current meters were used which were carefully rated both before and after the measurements of flow in the aqueduct were made. Two observers made measurements alternately with both meters and the average of all observations was used in the final computations. Simultaneous observations were made on the rate of flow through one of the Venturi meters by means of a manometer registering in parallel with one of the type "M" recorders. Those observations were made with flows at the rates of approximately 50, 65, 76, 92 and 112 million gallons per day. The leakage into the aqueduct between the power station and gaging station was also measured both before and after the measurements of flow were made. This was done by means of a small wooden weir placed temporarily in the aqueduct.

After thus rating one of the meters and determining the relation of the actual with the theoretical flow, the recording instruments were adjusted to agree with current meter ratings and then all four instruments tested at different rates of flow. It is believed that these meters now record within 2 per cent. of the true flows between rates of 50 and 110 million gallons per day. During the official test of the turbines, the water was also measured by a pitometer placed in the penstock line just below the inlet of the scroll case. The quantity of water discharged varied about 2½ per cent. between the current meter

and pitometer measurements, and settlement with the contractor was based on an average of these two measurements. The contract for the construction and erection of the hydraulic machinery was made with the S. Morgan Smith Company, of York, Pa., who guaranteed the 30-in. turbines to have an average efficiency of 82 per cent. when discharging 73, 122, 138 and 155 sec.-ft. under a net head of 90 ft. at a speed of 400 rev. per min. The average efficiency as determined by the previously described methods of water measurement was 80.5 per cent.

Operation of Plant.

The passage of the water into each of the penstock lines is through six 8-ft. by 2½-ft. openings in the granite walls of the upstream face of the dam where it enters the upper gate chamber. Here the water passes through 1-in. square-mesh copper wire screens; thence through two 6-ft. by 2½-ft. sluice gates into the 7-ft. diameter, vertical, brick-lined wells where, with reservoir full, it drops 111 ft.; thence through the 48-in. and 60-in. cast-iron penstock line as previously described. The loss in head due to friction through the various openings, wells and pipes with a flow of 110 million gallons per day is as follows:

Through 6 8-ft. x 2½-ft. granite openings	0.00 ft.
Through 1-in. square-mesh screens	0.35 ft.
Through 2 6-ft. x 2½-ft. sluice gates	1.05 ft.
Through 95.5 linear ft. of 7-ft. diameter brick-lined well	0.6 ft.
Through 15.5 linear ft. of 7-ft. diameter brick-lined well And 68 linear ft. of 48-in. cast-iron pipe, including 40-in. throat of Venturi meter	4.3 ft.
Through 44 linear ft. of 48-in. to 60-in. cast-iron pipe, including a 60-in. x 60-in. T and a 48-in. gate	1.25 ft.
Total	7.55 ft.

These losses were determined by point measurement and a mercurial column attached to the penstock line at the various points. Owing to the extreme variation in the elevation of the tail water in the aqueduct, the net head under which the plant

operates varies greatly with the number of machines running. With the plant operating at capacity, which it does about 75 per cent. of the running time, the over-all efficiency is about 77 per cent. when operating with unity power factor. The get-away of the water in the chamber under the generating room is considerably hindered by the presence of the penstock lines, draft tubes and supporting concrete piers.

The operating contract with the Connecticut River Transmission Company has now been effective a little over three years, during which time conclusive proof of the merits of the utilization of the available energy has been manifest. This contract guarantees to the Board an annual minimum total of 5 250 000 kw.hr., which includes a daily minimum of 17 500 kw.hr. on such days as the Lancaster Mills take this amount, provided the total amount of energy available to the Company is not less than 6 570 000 kw.hr. Should the total amount of energy available to the Company during each year be less than as above stated, then the Company shall be required to take — or if it does not take to pay for — only 80 per cent. of such available amount. In reckoning the amount of energy available, all flow of water from the Wachusett Reservoir into the aqueduct in excess of 875 000 000 gals. in a calendar week is excluded. The Board agrees to operate its plant so as to concentrate the flow of water into the particular hours of the week during which the Company desires electric energy, and to furnish the Company the largest amount of energy and the best service practicable without interfering with the reasonable requirements of the water for domestic purposes. It is understood that there may be times when the requirements of the water works will call for a complete shut-down of the plant for several days at a time.

The power plant is operated by employees of the Board, the normal running time being confined to two shifts of attendants working eight hours each. The entire operation of the plant being controlled from the main floor of the generator room, each shift is handled by an operator and helper. Occasional demands for energy from the Connecticut River Transmission Company require the plant to run twenty-four hours a day.

The running time and rate of output of the station is at all times subject to the orders of the chief dispatcher for the Connecticut River Transmission Company, who can, under the present contract, change the hours of running or the rate of output to best meet the requirements of their system, from a complete shut-down to the maximum output of the station, provided it does not interfere with the requirements for water. To meet these conditions and at the same time have protection to the apparatus, the two underground transmission cables are connected in parallel from the circuit breakers to the lightning arrester building, where both cables are connected to one of the overhead circuits.

No. 1 circuit breaker and relays are set for the capacity of one generator, while No. 2 is set for the capacity of two generators. If the plant is being operated at the maximum or three generators, both line breakers are closed. The fact that we have had no trouble with the circuit breakers although they have been repeatedly subjected to severe short circuits on the lines is in a large measure due to the setting of the relays, the time element being set at about 5 seconds, thus giving an opportunity for the initial value of the short-circuit current to decrease. Frequent inspection of the relay contacts which shunt the trip coils is made, as any foreign substance or burned spots which interfere with the contacts completely shunting the trip coils makes the breaker instantaneous in action. The price paid for the energy is $5.30 per thousand kw.hr. and the net profit after paying all operating expenses and taxes of a valuation of $125 000 is about $25 000 per year. The net returns from the operation of the plant would be considerably decreased after making deductions for interest, depreciation and insurance.

During the three years that the contract has been operative 79.9, 83.2 and 98.4 per cent., respectively, of the water drawn from the Wachusett Reservoir has been used for generating purposes before entering the aqueduct, which shows how well the requirements of both operating concerns are met under cöoperative management.

The plant was designed under the direction of Frederic

P. Stearns, chief engineer of the Metropolitan Water Works during the construction of the Wachusett Dam and Aqueduct, and consulting engineer during the design and installation of the power plant. He was assisted by William L. Puffer, electrical engineer, and by the engineers of the S. Morgan Smith Company and the Westinghouse Electric and Manufacturing Company, which firms furnished and installed the turbines and electrical apparatus, respectively. Dexter Brackett, chief engineer of the Metropolitan Water Works, had general charge of construction and installation. The plant was constructed under the immediate direction of E. R. B. Allardice, superintendent of the Wachusett Department, Metropolitan Water Works, while B. C. Thayer had immediate charge of the installation of the electrical apparatus for the Westinghouse Electric and Manufacturing Company. Since its completion, Mr. Thayer has been the electrical engineer in charge of the operation of the plant for the Metropolitan Water and Sewerage Board.

Vol. I JANUARY, 1914 No. 1

Boston Society of Civil Engineers

FOUNDED 1848

PROCEEDINGS

PAPER IN THIS NUMBER.

"Boston Foundations." J. R. Worcester.
(To be presented January 28, 1914.)

REGULAR MEETING.

A regular meeting of the Boston Society of Civil Engineers will be held on Wednesday, January 28, 1914, at 7.45 o'clock P.M., in

CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Business of the Meeting: To choose a committee of five to nominate officers for the ensuing year.

To canvass the letter ballot on the adoption of the resolution in relation to the flood control of the Mississippi River, as passed at the December meeting of the Society.

To act on the following amendment to the By-Laws adopted at the December meeting: Amend By-Law 8 by adding after the second paragraph the words, "Three dollars of the dues of each member, or such portion thereof as may be required, shall annually be applied to the payment of a subscription to the Journal of the Boston Society of Civil Engineers."

To act on a communication in relation to the establishment of a testing flume by the United States Government. (The communication is printed elsewhere in this number of the Journal.)

Mr. J. R. Worcester, past president of the Society, will read a paper entitled "Boston Foundations."

This paper is printed in this number of the JOURNAL.

S. E. TINKHAM, *Secretary.*

JOINT MEETING OF BOSTON ENGINEERS.

Wednesday Evening, February 4, 1914.

A JOINT meeting of the American Society of Mechanical Engineers, the Boston Society of Civil Engineers and the Boston Section, American Institute of Electrical Engineers, under the direction of the first named society, will be held Wednesday evening, February 4, 1914, at 8 o'clock, in Chipman Hall, Tremont Temple.

The subject of discussion will be: Recent Developments and Present Tendencies in Railroad Work, with respect to:

(*a*) Rolling stock. Discussion opened by Henry Bartlett, Mechanical Superintendent, Boston & Maine Railroad.

(*b*) Electrical equipment. Discussion opened by Frederick D. Hall, Electrical Engineer, Boston & Maine Railroad.

(*c*) Permanent way. Discussion opened by A. B. Corthell, Chief Engineer, Boston & Maine Railroad.

SPECIAL MEETING.

A special meeting of the Society will be held on Wednesday evening, February 14, 1914, at 8 o'clock P.M., at the Engineers Club.

Mr. G. F. Ahlbrandt, Metallurgical Engineer, will give an illustrated lecture on the Manufacture of Pure Iron Products.

FEBRUARY MEETING OF THE SANITARY SECTION.

A SPECIAL meeting of the Sanitary Section will be held Wednesday evening, February 4, 1914, at the Engineers Club, corner Commonwealth Avenue and Arlington Street.

Dinner will be served in the dining room on the fourth floor of the Club at 6 o'clock. Price, $1.25 per plate.

The meeting will begin promptly at 7.30 o'clock in the Assembly Hall, on the street floor. (Use Arlington Street door.) The subject for discussion will be, "The Measurement of the Flow of Sewage."

The discussion will be opened by Mr. George A. Carpenter, city engineer of Pawtucket, R. I., with a paper on "Sewage Measurement and Automatic Storm Overflow Control at Pawtucket, R. I."

This will be followed by a paper on "The Venturi Meter for Measuring Sewage," to be read by Mr. F. N. Connet, chief engineer of the Venturi Department of the Builders Iron Foundry, Providence, R. I.

Several other gentlemen have already agreed to take part in the discussion. Lantern slides will be used, and the reflectoscope will be available for showing photographs or cuts.

It is hoped that all members who have had any experience in this class of work will come prepared with written discussions which can be added to the papers.

Let us make this a meeting for practical discussion.

EDMUND M. BLAKE, *Chairman.*
FRANK A. MARSTON, *Clerk.*

MINUTES OF MEETINGS.

DECEMBER MEETING OF THE SOCIETY.

BOSTON, December 17, 1913. — A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, at 8.10 o'clock, President Frederic H. Fay in the chair; 120 members and visitors present.

By vote the reading of the record of the last meeting was dispensed with and it was approved as printed in the December *Bulletin.*

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Members — Messrs. George Winthrop Bowers, George C. Capelle and Edward Vincent Gartland.

Juniors — Halford Henry Ambler, Samuel M. Fox, Jr., and Jacob Max Sokoll.

The Secretary presented the memoir of our late associate, George I. Leland, which had been prepared by Mr. W. S. Johnson, the committee appointed for the purpose, and by vote it was accepted and ordered to be printed in the JOURNAL of the Society.

The following amendment to the By-Laws, proposed by the Committee on Publication and printed in the notice for this meeting, was then adopted by a unanimous vote: Amend By-Law 8 by adding after the second paragraph the words, "Three dollars of the dues of each member, or such portion thereof as may be required, shall annually be applied to the payment of a subscription to the JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS."

The consideration of the resolution in relation to the flood control of the Mississippi River was then taken up. The resolution, which was printed with the notice for this meeting, was as follows:

Whereas, the flood control of the Mississippi River is a problem demanding serious and immediate attention; and

Whereas, all such problems can best be handled by some central authority which, in addition to its own work, can direct and coöperate with the efforts of local interests; and

Whereas, owing to the great extent of territory affected, the United States Government is the only central authority available to handle this problem; and

Whereas, the improvement of the various rivers and harbors throughout the country can best be carried out by the cordial coöperation of the inhabitants of all sections; and

Whereas, we in Boston, vigorously promoting the development of this port and the commercial and industrial advancement of New England, realize that the proper control of the Mississippi River is a matter which not only affects the welfare of the whole country, but will materially benefit the manufacturing and commercial interests of Boston and New England, therefore, be it

Resolved, that the Boston Society of Civil Engineers, believing the levee system to be the most practicable method of regulating the Mississippi River floods, favors the passage of the measure now before Congress known as the Humphreys-Ransdell Bill, entitled "A Bill to Prevent Floods on the Mississippi River and Improve Navigation Thereon."

Mr. E. W. Howe moved to amend by striking out in the last paragraph the following words: "believing the levee system to be the most practicable method of regulating the Mississippi River floods." After a discussion by Messrs. E. W. Howe, F. B. Sanborn, H. A. Miller and A. H. Howland, the amendment was not adopted, 30 voting in favor and 31 against. The resolution as reported by the committee was then adopted, and the President announced that the resolution would now be submitted to the members in the form of a letter ballot for final action.

Past President James W. Rollins gave a very interesting account of the construction and repairs of the Brightman Street Bridge at Fall River. The talk was illustrated by lantern slides.

The President then introduced Mr. G. H. Perkins, superintendent of Refinery of Warren Brothers Company, who gave a lecture, illustrated by lantern slides and motion pictures, and entitled "Bitulithic Pavement and Warrenite Roadway."

After passing a vote of thanks to Mr. Perkins for his interesting lecture, the Society adjourned.

S. E. Tinkham, *Secretary.*

JANUARY MEETING OF SANITARY SECTION.

Boston, Mass., January 7, 1914. — A special meeting of the Sanitary Section of the Boston Society of Civil Engineers was held this evening in the Assembly Hall of the Engineers Club.

In accordance with the printed notice of the meeting, it was not planned to hold a special dinner preceding the meeting, but at the request of several of the members arrangements were made with the Club to serve the regular table d'hôte dinner to members of the Section. There were 30 present at this informal dinner.

The meeting of the Section was called to order in the Assembly Hall by Chairman Edmund M. Blake, at 7.45 o'clock.

The speaker of the evening was Mr. Charles H. Paul, construction engineer on the Arrowrock Dam of the United States Reclamation Service, who gave a most interesting and instruc-

tive account of the construction methods employed on the dam, and the general facts in regard to the project.

Among other things, the precautions observed to keep the construction camp in a sanitary condition were described in detail. The value of the talk was greatly increased by the lantern slides used, a large portion of which were in colors. Considerable interest was aroused in the subject, as was shown by the number of questions brought out in discussion.

Following the discussion, the Chairman exhibited a few slides showing some of the work being done by the Massachusetts State Board of Health, on the improvement of the Neponset River.

There were 125 present at the meeting.

FRANK A. MARSTON, *Clerk.*

ESTABLISHMENT OF A TESTING FLUME BY THE UNITED STATES GOVERNMENT

We, the undersigned, respectfully submit to the Boston Society of Civil Engineers the following arguments in favor of a government testing flume; and we respectfully request that such action be taken in connection with the establishment of a testing flume as may be in accordance with the methods of the Society.

Water wheels have increased so much in size in recent years, and are operated under so much higher heads, that there is now no place in the United States where they can be adequately tested before their final installation.

The Holyoke Testing Flume, the only place of its kind in this country, has done more for the improvement in efficiency of water-wheel runners than can properly be estimated. The Holyoke Flume, however, is no longer large enough nor does it have sufficient head to meet all of the present-day needs. What the country really needs is a testing flume large enough to test properly not only the largest runners and their settings, but to provide for reasonable future requirements. The head on a flume of this kind should be variable up to at least 150 ft.

The flume should be suitable for conducting on a large scale experiments in the various methods of measuring water under conditions such as are found in actual operating plants. The art of water-wheel design is still in rather a crude state and needs such authentic and reliable information as the proposed flume will furnish.

Niagara Falls has been suggested as a proper place to establish such a testing flume, and as a matter of fact appears to be the only suitable place. It has the advantage of geographical location also and a relatively large supply of water; as the total amount of water used in a testing flume is a small item, there certainly could be no opposition from those interested in the conservation of Niagara Falls. The use of water would be intermittent and of comparatively short duration. The above mentioned variable heads up to at least 150 ft. are obtainable at this point.

A flume of this kind would be used not only by water-wheel manufacturers, but would be of inestimable value in conserving the water-power resources of the country for the following reason:

Considering the amount of money expended in this country in connection with water-power development, it is a matter of vital interest to the entire country that these installations should be built in a way to give maximum operating efficiency, or, in other words, to get the most power out of the water available. Where the water supply is limited, as it is in most cases, the success or failure of the development often depends upon the efficiency of water-wheel runners or settings.

A fundamental fact concerning water-wheel installations is that a poor runner can never be made a good one by a good setting, while the performance of a good runner can be spoiled by a poor setting. There are many water-wheel installations with wheels permanently built into solid concrete that are working twenty-four hours a day, year in and year out, actually giving from five to ten or more per cent. less efficiency than they would be giving had such a testing flume as is now suggested been available to the designers.

The government conducts experimental stations along agricultural lines, as well as for the testing of fuels, structural

materials, etc., and the work of these stations is certainly justified, as it is of such a technical character that neither private individuals nor even institutions would be likely to undertake it on their own account.

The Geological Survey is doing invaluable work in connection with studies of stream flow and control. Why should not the government take up experiments in the efficient use of water? Water power that passes a plant unused or used inefficiently represents a sheer waste, and the prevention of this waste means a saving of just so much fuel.

The ordinary difference between loss of power from fuel and from water is, that water power when wasted is irretrievable, while fuel not used is saved for future purposes. This means a double saving. Moreover, in contrast to most other government experiment stations, the Niagara flume, by charging a reasonable fee for the testing, could probably be made nearly if not entirely self-supporting.

The only argument so far advanced against the establishment of a testing flume by the government is the political one. Judging by past history, a hydraulic testing department might have the tendency to extend beyond the legitimate needs for which it was created, but if such a department were established, its work could be kept within its natural field of activity. If the personnel of this department were wisely chosen, there could be no doubt of its success.

It is the sincere hope of the undersigned that the various engineering societies of the country will see the importance of such a project and all work together for its establishment.

Signed:

I. N. HOLLIS,
Pres. Worcester Polytechnic Institute;
Past Vice-President, A. S. M. E.;
Past President, Boston Society C. E.

GEORGE F. SWAIN,
Pres. Am. Soc. C. E.;
Chairman Boston Transit Commission;
Prof. Engr., Harvard University;
Past President Boston Society C. E.

CHARLES T. MAIN,
Consulting Engineer;
Past President Boston Society Civil Engineers.

A. F. SICKMAN,
Hydraulic Engr., Holyoke Water Power Co.

FREDERIC H. FAY,
President Boston Society of Civil Engineers; Div. Engr., Boston Public Works Dept.

R. A. HALE,
Principal Ass't. Engr., Essex Co., Lawrence, Mass.

A. T. SAFFORD,
Lecturer, Hydraulic Engineering, Harvard College;
Assist. Engr., Locks and Canals, Lowell.

I. E. MOULTROP,
Edison Ill. Co. of Boston;
Chairman Prime Movers Com., N. E. L. A.

C. M. ALLEN,
Prof. of Hydraulic Engineering, Worcester Polytechnic Institute.

H. K. BARROWS,
Consulting Engineer (Barrows & Breed), Boston;
Associate Professor Hyd. Engr., M. I. T.

H. J. HUGHES,
Associate Professor Civil Engineering, Harvard University.

F. B. SANBORN,
Prof. of Civil Engineering, Tufts College.

DWIGHT PORTER,
Prof. Hydraulic Engr., M. I. T.

I. W. McCONNELL,
Hydraulic Engr., Stone & Webster Engineering Corp'n; formerly with U. S. Government Reclamation Service.

J. F. VAUGHAN,
Hydraulic Engr., Stone & Webster Engineering Corp'n, Boston.

BINDING THE JOURNALS.

MEMBERS who wish the Secretary to attend to the binding of their numbers of the *Journal* of the Association of Engineering Societies are requested to send them to Room 715, Tremont Temple, Boston, before March 1.

Arrangements have been made by which members can have the *two* volumes bound in *one* for 70 *cents*, or each volume bound separately for 50 *cents;* the style of binding to be the

same and uniform with that of former years. Mark clearly which way it is desired the binding should be done.

APPLICATIONS FOR MEMBERSHIP.

[January 14, 1914.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

DALTON, THOMAS VINCENT, Allston, Mass. (Age 23, b. Newton, Mass.) Graduate of Mechanic Arts High School, Boston, 1910; 1910 to 1912, student with private engineer; 1910 to 1911, rodman and inspector with Boston Elevated Railway Company; 1911 to 1912, mechanical draftsman with Boston & Albany R. R.; 1912 to 1913, leveler with N. Y., N. H. & H. R. R.; April to September, 1913, foreman and engineer for J. H. Sullivan Company, contractors; September, 1913, to date, sewer inspector, city of Malden, Mass. Refers to H. S. Draper, H. W. Estey, H. M. Johnson and E. R. Kimball.

FOOTE, FRANCIS CHANDLER, Boston, Mass. (Age 20, b. Plattsburgh, N. Y.). Third year student in sanitary engineering at Massachusetts Institute of Technology; Secretary of M. I. T. Civil Engineering Society. Refers to C. F. Allen, C. B. Breed, A. E. Burton, Dwight Porter, A. G. Robbins and C. M. Spofford.

EMPLOYMENT BUREAU.

The Board of Government has established an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society rooms two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

Men Available.

182. Age 22. Graduate of Technical High School and has completed courses in Surveying and Railroad Engineering at Boston Y. M. C. A.; now a student at Franklin Union. Has had eight months' experience as draftsman and transitman with B. & M. R. R., two months as draftsman on land and road construction work, and since July, 1913, has been with Massachusetts Highway Commission as rodman and transitman. Desires position as draftsman or transitman with good engineer, where experience obtained will be of value. Salary desired, $60 per month.

207. Age 26. Has high school education and has taken Y. M. C. A. and I. C. S. courses. Has had five years' experience, chiefly as draftsman and designer, including one year with Aberthaw Construction Company as concrete designer, and nine months with International Railways of Central America as draftsman and surveyor. Desires position as assistant engineer, designing draftsman or estimator (quantitative or cost). Minimum salary desired, $22.50 per week.

208. Age 26. Has had five years of high school work, three years of higher mathematics in evening high school, and one season at Boston Franklin Union. Has had five years' experience, including one year as rodman on railroad work and four years in mechanical and electrical work. Desires position as transitman or rodman. Salary desired, $15 per week.

209. Age 25. Two years' college course at General Engineering College, and two years at City and Guild Institute,

London, England. One year's experience as assistant location engineer in Katauja Kongo, and two years as engineer officer in field company; also experience as rodman with B. & A. R. R. Desires position as rodman, draftsman or inspector. Salary desired, $16 per week.

210. Technical training at Massachusetts Institute of Technology. Four years' experience in structural drafting, and nine years' experience as assistant superintendent of municipal water works, having full charge of all pipe construction and maintenance work, keeping of records and writing of reports. Has had practical experience in handling workmen, and has had charge of drafting department of water works.

211. Age 23. Graduate of Thayer School of Civil Engineering, Darmouth College. Has had three years' experience as transitman and rodman on state highways in Rhode Island and Connecticut; also experience as draftsman and inspector of concrete, and as concrete designer and detailer. Desires position as concrete inspector or as designer of reinforced concrete and detailer. Salary desired, $20 per week.

212. Age 27. Over seven years' experience, mostly as transitman and draftsman on railroad work, including five years with Boston Elevated Railway Company. Desires position as transitman or draftsman. Salary desired, $75 per month.

213. Age 24. Graduate of University of Maine, 1913, with degree of B.S. in civil engineering. Has since been levelman on state highway work in Maine, and chainman in construction department, B. & M. R. R., at Brattleboro, Vt. Desires position as instrument-man. Salary desired, $75 per month.

214. Age 29. Graduate of Massachusetts Institute of Technology, 1907. Has had over six years' experience, including general surveys; drafting; three years of design, laying out and construction of pipe lines, conduits, dam and general construction work; and five months as resident engineer on construction of filtration plant. Desires general construction work.

LIST OF MEMBERS.

ADDITIONS.

Ambler, Halford H. . . . . 207 Washington St., Winchester, Mass.
Bowers, George W. . . . . 359 Westford St., Lowell, Mass.
Fox, Samuel M., Jr. 176 Newbury St., Boston, Mass.

CHANGES OF ADDRESS.

Alden, Howard K. . . . . 10 So. 5th St., Oneonta, N. Y.
Bayley, Frank A. . . . . 399 Broadway, Cambridge, Mass.
Burke, John R. . . . . 78 Devonshire St., Boston, Mass.
Cobb, William A. . . . . 21 Hampshire St., Auburn, Me.
Dutton, Charles H. . . . . 94 Congdon St., Providence, R. I.
Fielding, William J. . . . . 16 Gorham Rd., West Medford, Mass.
Hutchins, Edward,
Care of International Paper Company, 30 Broad St., New York, N. Y.
Jaques, William H. . . . . 142 Beacon St., Boston, Mass.
Kelley, Mark E. . . . . 30 Beckett St., Peabody, Mass.
Manley, Henry, Jr. . . Care of Public Service Commission, State of New York,
Queens Plaza Court, Long Island City, N. Y.
Mann, John L. . . . . 29 Broadway, Room 1503, New York, N. Y.
Morse, Charles F. . . . . 68 Summer St., Malden, Mass.
Nash, Philip C. . . . . 35 Irma Ave., Watertown, Mass.
Newman, Rolf R. . . . . 1070 Lemon St., Riverside, Cal.
Nolan, Conrad . . . . 146 Oxford St., Cambridge, Mass.
Ramsom, Horace U. . . . . 27 Orchard St., Belmont, Mass.
Soutar, George P. . . . . 30 Warren St., West Lynn, Mass.
Willard, Ernest C. . . . . The Bedford, Spokane, Wash.

LIBRARY NOTES.

Recent Additions to the Library.

U. S. Government Reports.

Annual Report of Director of Office of Public Roads for 1912–13.

State Reports.

Massachusetts. Annual Report of State Board of Health for 1912.

Massachusetts. Suppression of Tuberculosis. Hiram F. Mills.

New York. Annual Report of Public Service Commission for First District for 1912, Vol. I.

City and Town Reports.

Detroit, Mich. Annual Report of Department of Parks and Boulevards for 1913.

Fitchburg, Mass. Report to Water Commissioners on Additional Water Supply, by Metcalf & Eddy. Gift of authors.

Philadelphia, Pa. Report of Transit Commissioner, July, 1913. 2 vols.

Miscellaneous.

Buff & Buff Mfg. Co. Catalogue of Surveying Instruments, 1914.

Institution of Mechanical Engineers, London. Proceedings for 1912, Parts 3–4, and for 1913, Parts 1–2.

National Board of Fire Underwriters. List of Gas, Oil, Mechanical and Chemical Appliances, July, 1913. Reports on the following cities: Amsterdam, N. Y.; Danville, Ill.; Fort Wayne, Ind.; Hackensack, N. J.; Harrisburg, Pa.; Hot Springs, Ark.; Little Rock, Ark.; Newark, N. J.; Oshkosh, Wis.; Portland, Me.; Scranton, Pa.; Sioux City, Ia.; Troy, N. Y.

Permanent International Association of Congresses of Navigation. Minutes of Board Meeting at Willebroeck, June 19, 1913; Elements of Cost of Canal Transport, by G. Renaud.

Test of 40-foot Reinforced Concrete Highway Bridge. D. A. Abrams.

The following numbers of the Minutes of the Proceedings of the Institution of Civil Engineers, London, England, are needed to complete the Society's files: Vols. 4 to 58, inclusive; Vols. 163 to 185, inclusive; and Vols. 190 (Part IV, 1911–12) to date, inclusive. Can any member furnish us with any of these volumes or give us information as to where and how they can be obtained?

A member suggests that Emerson's "Hydro-Dynamics" be added to the library. The book, it seems, is out of print, and a search through the second-hand bookstores has failed to bring

a copy to light. If any member has a copy that he does not care to keep, we should be very glad to place it on the shelves.

We wish to express our appreciation of the prompt and generous response to our request in the December *Bulletin* for certain numbers of the Proceedings of the Connecticut Society of Civil Engineers. Our file is now complete from 1885 to 1913.

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before the first of each month.)

Commonwealth of Massachusetts. — METROPOLITAN PARK COMMISSION. — *Woburn Parkway.* — Work of construction of parkway on the westerly side of Horn Pond is in progress.

METROPOLITAN WATER AND SEWERAGE BOARD. — *Sewerage Works.* — Work on Sections 68 and 70, new Mystic Sewer, at Winchester, is in progress. Contract for Section 69 has been awarded to the Henry Spinach Co.

DIRECTORS OF THE PORT OF BOSTON. — *Commonwealth Pier No. 1* (known as Eastern Railroad Pier). — The work of removing existing buildings and pile structures on this pier is being done by Thomas A. Elston. Designs are now under way for the construction of a new pier on this site.

On January 7 bids were opened for the dredging of the areas adjacent to this pier to depths of 35 and 40 ft. below mean low water.

Commonwealth Pier No. 5. — The artificial stone work and brick masonry for the headhouse are well under way. On the second floor of the central shed a considerable force is employed in building partitions in the different rooms for passenger accommodations. In the westerly side of the headhouse a salt-water intake well is being sunk to a depth of 11 ft. below mean low water.

It is proposed to dredge the area between the pier and the main ship channel to 40 ft. deep at mean low water.

Commonwealth Pier No. 6 (Fish Pier). — The work of constructing paving, drainage pipes, etc., on this pier has been suspended for the present. (For report on superstructure, consult Mr. H. S. Adams, Ames Building.)

Railroad Freight Yard. — Bids for the construction of a railroad freight yard, capable of accommodating about 400 cars with $6\frac{1}{3}$ miles of track, on the Commonwealth Flats, will be received until Wednesday, January 14.

Viaduct. — The work of constructing the foundations for the viaduct from Commonwealth Pier No. 5 to Summer Street is practically completed.

Heating Plant. — The superstructure for the heating plant is under way.

Dry Dock. — The bulkheads being constructed in connection with the dry dock are partially completed for a distance of about 800 lin. ft.

Dredging. — A channel 24 ft. deep at mean low water and 100 ft. wide on the bottom is being dredged from the main ship channel to the pier leased by the Metropolitan Coal Company.

The existing channel at Cottage Park, Winthrop, is being dredged to give a depth of 6 ft. at mean low water, and the work is nearly completed.

Boston Transit Commission. — *Boylston Street Subway.* — The Boylston Street Subway extends from Kenmore St. near the intersection of Commonwealth Ave. and Beacon St. to the southwest corner of the Common near Park Square, a distance of about 8 000 ft., and is nearly completed.

The uncompleted portions of the work (excepting the interior finish of the two stations not yet ready for contract) are a part of the station at Massachusetts Ave., a part of the station at Copley Square, consisting of the lobby under Dartmouth St., and a part of Sect. 5, which extends from Arlington St. to and connects with the Tremont St. Subway near Park Square. Work is in progress in all of these places. The Boston Elevated Ry. Co. is engaged in installing ducts and lighting conduits in the subway.

The contractor for the above-mentioned work is the Hugh Nawn Contracting Co.

Dorchester Tunnel. — Section B includes the proposed station in Summer St., which will extend from near Washington St. east to Arch St. The work of underpinning the buildings on Summer St. along the line of the work is practically completed. Concrete sidewalls and steel columns and roof beams with concrete in roof are being placed. The new cast-iron sewers are mostly in place. New manholes, pipes and conduits are being laid over the roof in advance of the backfilling. The contractor is the Hugh Nawn Contracting Co.

Section C is located in Summer St. and extends from near Arch St. to Dewey Square, a distance of about 1 018 ft. About two thirds of its length is to be built by tunneling. The structure is to be mainly of reinforced concrete. The contract has been awarded to the James J. Coughlan Co. and the work has been started.

East Boston Tunnel Extension. — Section G extends in Court St. from the easterly side of Cornhill westerly to Stoddard St. The structural work from near Brattle St. to Stoddard St. is nearly completed. The construction of a part of the station under and near the present Scollay Square station is in progress. Isaac Blair & Company, Inc., is the contractor.

Section J extends from Staniford St. to North Russell St. The incline in Cambridge St. between Chambers and North Russell St. has been built. Excavation is proceeding between Staniford and Chambers St. and the walls of the tunnel are partly built. The new portion of Cambridge St. to the north and west of the incline has been paved and is open for traffic. Coleman Bros. are the contractors.

City of Boston. — Public Works Department, Highway Division, Paving Service. — Work is in progress on the following streets: Summer St., from B St. to Viaduct to Pier No. 5, building wall; Cliftondale St., from Norfolk St. to Kittredge St., asphalt macadam; Norfolk St., from Washington St. to R. R. Bridge, bitulithic; Gayland St., from West Cottage St. to Judson St., tar macadam.

Sewer and Water Division. — *Sewer Service.* — The following work is in progress:

In alley west of Tremont St. between Dartmouth and West Canton St. and between West Newton St. and Concord Square; Haines Weaver Gravity Concrete Mixer on first section and cube mixer on the second. Berkeley St. at Stuart St., 8-in. sanitary sewer and 4 ft. 3 in. concrete surface drain; Haines Weaver Mixer at work. Private land off Summer St. near Cass St., Spring St. Station, West Roxbury, 5-ft. 3 in. circular surface drain, building of vitrified segment sewer blocks. Gately Wharf, Albany St., at foot of Union Park St., Concrete gravity outlet sewer 10 ft. 6 in. x 4 ft. 10 in. and force main sewer 10 ft. 6 in. x 2 ft. 9 in.

New York, New Haven & Hartford Railroad. — Clinton, Mass. Elimination of Grade Crossings. Work on the Boston & Maine Railroad now in progress is the building of a passenger station, the cutting down of the former grade of the roadbed and the change of through traffic to the new low level main line tracks in their temporary position. This change of traffic will allow the completion of the depression of the roadbed, the completion of the foot subway at Sterling St. and the building of the new transfer yard between the two roads. Work on the station has been curtailed by the non-arrival of materials, and the severe weather of the past week has generally retarded the work.

Work on the New Haven now in progress is the completion of the masonry bridges at the crossing of the Boston & Maine Railroad. The work is curtailed on account of the weather conditions.

Quincy, Mass. — The Fore River Shipbuilding Co. has the following new work in progress:

Battleship *Rivadavia* for the Argentine Republic.

U. S. Battleship *Nevada*.

U. S. Submarine Tender *Fulton*.

Nine U. S. submarine boats.

U. S. Torpedo Boat Destroyers *Cushing* and *No. 57*.

Molasses Tanker *Amolco* for the Boston Molasses Co.

General Cargo Steamers *Atlantic* and *Pacific*, for the Emery Construction Company.

Abertthaw Construction Company. — New Fish Pier, South Boston: The Aberthaw Construction Co. is building the cold storage plant for the Commonwealth Ice and Cold Storage Co. The foundations are now going in. These are of reinforced concrete over piles. Big concrete girders distribute the weight of the piers over the mat. The power house walls, 72 ft. in height, have been run up, using steel forms. There is a good concrete handling plant in operation, and some of the details of the contractor's layout are worth studying. The job is on the street and can be examined readily.

Vol. I FEBRUARY, 1914 No. 2

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

PAPERS IN THIS NUMBER.

CURRENT DISCUSSIONS.

Paper.	Author.	Published.	Discussion Closes.
1. "Boston Foundations."	J. R. Worcester.	Jan.	Mar. 15.

REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on Wednesday, February 18, 1914, at 7.45 o'clock P.M., in

CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. Luis G. Morphy will read a paper on "Railroad Improvements at Worcester, Mass." The paper will be illustrated with lantern slides.

S. E. TINKHAM, *Secretary*.

ANNUAL MEETING OF THE SOCIETY.

The annual meeting of the Society will be held on Wednesday, March 18, 1914, at the Boston City Club, 9 Beacon Street, Boston, where the very satisfactory accommodations of former years have been secured.

The Annual Meeting for the transaction of business and the announcement of the result of the letter ballot for officers will be held at 12 o'clock M. A short address will be made by the retiring President.

The annual dinner will be served at two o'clock in the auditorium of the club.

In the evening a smoker will be held in the auditorium, at which light refreshments, music and other entertaining features may be expected.

Further details will be furnished in a special circular to be sent out early next month and in the March JOURNAL.

ANNUAL MEETING OF THE SANITARY SECTION.

THE annual meeting of the Sanitary Section, Boston Society of Civil Engineers, will be held Wednesday evening, March 4, 1914, in the Assembly Hall of the Engineers Club, corner of Commonwealth Avenue and Arlington Street.

A special dinner will be served to members and guests in one of the private dining rooms of the Club at six o'clock. Price, $1.25 a plate.

The business meeting will be called to order at 7.30 o'clock. The business to come before the meeting includes: Approval of minutes of previous meetings, report of Special Committee on Sewerage Statistics, report of Executive Committee, report of Nominating Committee, election of officers and members of Executive Committee for the ensuing year.

The Section is fortunate in having secured for the speaker of the evening, Mr. George S. Webster, chief engineer of the Bureau of Surveys, Philadelphia. The subject of Mr. Webster's talk will be announced by circular a few days previous to the meeting. It may confidently be expected that the talk will be

of considerable interest and value because of Mr. Webster's long engineering experience. Lantern slides will be used.

EDMUND M. BLAKE, *Chairman.*
FRANK A. MARSTON, *Clerk.*

MINUTES OF MEETINGS.

JANUARY MEETING OF THE SOCIETY.

BOSTON, January 28, 1914.—A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order by the President, Frederic H. Fay, at 8 o'clock. There were 151 members and visitors present.

By vote the reading of the record of the December meeting was dispensed with, and it was approved as printed in the January number of the JOURNAL.

On motion of Mr. E. W. Howe, it was voted that the chair appoint a committee of three to suggest to the meeting the names of five members to serve as a committee to nominate officers for the ensuing year. The chair appointed as that committee Messrs. E. W. Howe, R. E. Curtis and L. E. Moore. Later in the meeting this committee reported the following names as members of the Nominating Committee: Messrs. Henry F. Bryant, chairman; Edgar S. Dorr, Luzerne S. Cowles, Frank B. Sanborn and Harry E. Sawtell. On motion of Mr. F. P. Stearns, it was voted to accept the report and the members named were elected as the Nominating Committee.

The President announced that he had appointed as tellers to count the letter-ballot in relation to the resolution on the Flood Control of the Mississippi River, Messrs. W. S. Johnson, R. S. Weston, C. M. Spofford and C. B. Breed. The Secretary read a communication from Prof. George F. Swain, president of the American Society of Civil Engineers and past president of this Society, in which he urged that final action be not taken on the resolution until a committee of the American Society of Civil Engineers, which has been appointed to consider the

whole matter, shall have made its report. Mr. Johnson, for the tellers, submitted the result of the canvass of the letter-ballot. On motion of Mr. Bryant, the Secretary was directed by vote not to publish the result of the letter-ballot until otherwise instructed by the Society.

The following amendment to the By-Laws passed at the last meeting was, by a unanimous vote, passed a second time as required by the By-Laws: Amend By-Law 8 by adding after the second paragraph the words, "Three dollars of the dues of each member, or such portion thereof as may be required, shall annually be applied to the payment of a subscription to the JOURNAL of the Boston Society of Civil Engineers."

The communication in relation to the establishment of a testing flume by the United States Government, printed in the January number of the JOURNAL, was then considered, and on motion of Mr. A. T. Safford it was voted: That the communication be referred to the Board of Government with the suggestion that the attention of the American Society of Civil Engineers be called to the communication, if the Board thinks it wise.

Mr. Joseph R. Worcester then presented his paper on "Boston Foundations," printed in the January number of the JOURNAL, and gave a brief abstract from the paper.

The paper was discussed by Messrs. L. M. Hastings, F. P. Stearns, E. W. Howe, H. F. Bryant, L. B. Manley and others. Mr. Manley described particularly the settlement of the tower of the Old South Church and the work of constructing the subway on the Boylston Street side of the church, showing a number of lantern slides illustrating the work. These discussions will be printed in the March number of the JOURNAL.

Adjourned.

S. E. TINKHAM, *Secretary.*

MEMBERSHIP CARDS.

The membership cards for 1914 are now ready for distribution and one will be mailed to any member who applies to the Secretary.

APPLICATIONS FOR MEMBERSHIP.

[January 31, 1914.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

BILDT, AUGUST FREDRIK, Boston, Mass. (Age 58, b. Onsala, State of Halland, Sweden.) Graduate of Eidgenössische Polytheenicum zu Zürich, Switzerland, 1884. Draftsman and designer of structural work with Boston Bridge Works, 1886 to 1892; Baltimore & Ohio Bridge Division, April to August, 1892; King Bridge Works, 1892 to 1893; Dominion Bridge Company, 1893; Pittsburg Bridge Company, 1893 to 1896: Carnegie Steel Company, 1896; Boston Transit Commission, 1896 to 1899; Boston Elevated Railway, 1899 to 1902; City of Boston, Bridge Department, 1902 to date. Refers to D. H. Andrews, J. E. Carty, F. H. Fay, G. H. Stearns, S. E. Tinkham and J. R. Worcester.

LANGLEY, MILES ERSKINE, South Boston, Mass. (Age 23, b. Vancouver, B. C.) Graduate of Massachusetts Institute of Technology, department of civil engineering, 1913; has taken about one-half year's work toward Master's degree in civil engineering. Has served as timekeeper on railroad construction in Oregon and as foreman on street mains for gas company in Watertown; is now computer for Lowell Observatory. Refers to C. F. Allen, H. K. Barrows, C. B. Breed and C. M. Spofford.

EMPLOYMENT BUREAU.

The Board of Government has established an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society rooms two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

Men Available.

215. Age 36. Graduate of Massachusetts Institute of Technology, civil engineering course, 1900. Since September, 1900, has been with Boston & Albany Railroad on variety of work; has served as inspector, designer and in charge of work; for two years was assistant division engineer, and for past four years has served as supervisor of bridges and buildings. Desires position in engineering or maintenance-of-way department of railroad or in construction department of corporation. Salary desired, $150 per month.

LIST OF MEMBERS.

ADDITIONS.

Sokoll, Jacob M. . . . . 83 Poplar Street, Boston, Mass.

CHANGES OF ADDRESS.

Dutton, Charles H. . . . . Rhode Island State College, Kingston, R. I.
Fuller, William B. 150 Nassau Street, New York, N. Y.
Linenthal, Mark . . . . 78 Devonshire Street, Boston, Mass.
Rice, James . . . . 151 West 64th Street, New York, N. Y.
Small, Gilbert . . . . 3 Moody Street, Waltham, Mass.

LIBRARY NOTES.

Recent Additions to the Library.

U. S. Government Reports.

Metallurgical Coke. A. W. Belden.

Object-Lesson and Experimental Roads, and Bridge Construction, 1912-13.

Ohio and Mississippi Floods of 1912. H. C. Frankenfield.

State Reports.

Massachusetts. Survey of Lands and Preparing Plans for Land Court. Registration of Land Titles and the Land Court.

New York. Final Report of Board of Consulting Engineers, Commission of Highways, 1913. Gift of Harold Parker.

New York. Supplement to Annual Report of State Engineer and Surveyor for 1912, Vol. II.

New York. Wood-Using Industries. John T. Harris.

South Carolina. Wood-Using Industries. Stanley L. Wolfe.

City and Town Reports.

Boston, Mass. Annual Report of Transit Commission for 1913.

Boston, Mass. Annual Report of Public Works Department for 1912.

Chicago, Ill. Nineteen Local Governments in Chicago.

Columbus, O. Report on Flood Protection. Gift of Alvord & Burdick.

New York, N. Y. Reports, letters, etc., of Board of Water Supply on City Tunnel and Delivery of Catskill Water, 1912.

Miscellaneous.

American Locomobile. George S. Cooper.

American Institute of Mining Engineers. Transactions for 1913.

Board of Arbitration. Report in Controversy between Boston Elevated Railway Company and Boston Carmen's Union; Clauses Agreed upon between Street and Electric Railway Employees and Boston Elevated Railway Company. Gift of H. S. Knowlton.

Carnegie Steel Company. Pocket Companion, 1913.

Master Car Builders' Association. Proceedings for 1913, 2 vols.

National Association of Cement Users. Proceedings, 1905–11, Vols. I–VII inclusive.

National Fire Protection Association. Specifications for Construction of Standard Building; Story of National Fire Protection Association and List of Publications; Suggested Ordinances for Small Municipalities; Suggested Ordinance Regulating Use, etc., of Inflammable Liquids.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before the 25th of each month.)

Commonwealth of Massachusetts. — METROPOLITAN PARK COMMISSION. — *Woburn Parkway.* — Work of construction of Woburn Parkway is in progress.

Charles River Reservation, Lower Basin. — Work of construction of retaining wall along Broad Canal on property of Horgan Estate is in progress.

DIRECTORS OF THE PORT OF BOSTON. — *Commonwealth Pier No. 1* (known as Eastern Railroad Pier). — The work of removing existing buildings is nearly completed, dredging has been begun and plans are well under way.

Viaduct. — The foundations for the viaduct from Commonwealth Pier No. 5 to Summer Street are completed and the ramp is nearly done.

Heating Plant. — The superstructure for the heating plant is under way.

Dry Dock. — The bulkheads being constructed in connection with the dry dock are partially completed for a distance of about 800 lin. ft.

Commonwealth Pier No. 5. — The artificial stone work and brick masonry for the headhouse are well under way. On the second floor of the central shed a considerable force is employed in building partitions in the different rooms for passenger accommodations. In the westerly side of the headhouse a salt-water intake well is being sunk to a depth of 11 ft. below mean low water.

New York, New Haven & Hartford Railroad. — Clinton, Mass. Elimination of Grade Crossings. Work on the Boston & Maine Railroad now in progress is the erection of a passenger station and the excavation for the final section of the subway for pedestrians in Sterling St. The Boston & Maine traffic has been changed to the new low level tracks in their temporary position and the work of excavating the remainder of the Boston & Maine roadbed has been deferred until the weather moderates. All the work is necessarily curtailed on account of weather conditions.

Work on the New Haven Road is the filling of the transfer track between the two roads. It is hoped that by the middle of February the traffic may be transferred from the high level New Haven tracks to the low level Boston & Maine tracks, which will allow the abandonment of the low level track now in service between the two railroads and the elimination of all grade crossings in the town of Clinton.

Quincy, Mass. — The Fore River Shipbuilding Co. has the following new work in progress:

U. S. Battleship *Nevada*.

U. S. Submarine Tender *Fulton*.

Nine U. S. submarine boats.

U. S. Torpedo Boat Destroyers *Cushing* and *No. 57*.

General Cargo Steamers *Atlantic* and *Pacific*, for the Emery Construction Company.

Aberthaw Construction Company. — The cold storage plant for the Commonwealth Ice and Cold Storage Company is progressing with little delay on account of the weather. The structural steel is being erected on two buildings and will be started on the third within a week. The Aberthaw Construction Company has also started the construction of four mills for the Highwood Company in New Haven, two of reinforced concrete, the others with steel truss roofs. The excavation for these is nearly finished.

Vol. I MARCH, 1914 No. 3

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

PROCEEDINGS

PAPERS IN THIS NUMBER.

CURRENT DISCUSSIONS.

Paper.	Author.	Published.	Discussion Closes.
1. "Boston Foundations."	J. R. Worcester.	Jan.	Mar. 15.
2. "Main Drainage Works Proposed for New York."	Geo. A. Soper.	Feb.	April 15.
3. "Fall River Bridge."	J. W. Rollins.	Feb.	April 15.

SIXTY-SIXTH ANNUAL MEETING.

THE annual meeting of the Boston Society of Civil Engineers will be held at the Boston City Club, 9 Beacon Street, Boston, on Wednesday, March 18, 1914.

As previously announced, the annual meeting this year will consist of three principal features: a business meeting at noon, the annual dinner in the afternoon, and the smoker in the evening.

Business Meeting. — The annual meeting required by the Constitution will be called to order at 12 o'clock M., in Rooms 4 and 5, on the third floor of the Club House.

BUSINESS. — Announcement of the election of new members.

To receive the annual reports of the Board of Government, of the Treasurer and of the Secretary.

To receive the annual reports of the several special committees.

To reappoint the several special committees.

Announcement of the result of letter-ballot for officers for the ensuing year.

Presentation of the Desmond FitzGerald Medal.

Address of the retiring President.

Annual Dinner. — The 32d annual dinner will be served at 2 o'clock P.M., in the auditorium on the fourth floor of the Club House.

At 3.30 o'clock Mr. Nelson P. Lewis, Chief Engineer, Board of Estimate and Apportionment of the City of New York, will give an illustrated talk on "City Planning from the Standpoint of the Engineer."

Smoker. — The usual informal smoker will be held in the auditorium at 7 o'clock P.M.

S. E. TINKHAM, *Secretary.*

SPECIAL MEETING, MARCH 25, 1914.

A SPECIAL meeting of the Society will be held in the Society Rooms, 715 Tremont Temple, on Wednesday evening, March 25, 1914.

Mr. Leslie M. Allen will read a paper entitled "Cost Accounting on Construction Work."

If you cannot find it convenient to be present at the meeting, any discussion of the paper you may desire to offer will be read by the Secretary.

MINUTES OF MEETINGS.

FEBRUARY MEETINGS OF THE SOCIETY.

BOSTON, February 11, 1914. — A special meeting of the Boston Society of Civil Engineers was held this evening at the Assembly Hall of the Engineers Club, and in the absence of the President and Vice-Presidents, Mr. Robert Spurr Weston, a Director of the Society, presided. There were 90 members and visitors present.

The speaker of the evening was Mr. G. F. Ahlbrandt, metallurgical engineer, who gave a very interesting talk on "Pure Iron versus Steel." The talk was illustrated by a large number of lantern slides.

Prof. Wm. H. Walker, Prof. Henry Fay and others took part in the discussion which followed.

After passing a vote of thanks to Mr. Ahlbrandt for his courtesy in presenting the matter to the Society, the meeting adjourned.

BOSTON, February 18, 1914. — A regular meeting of the Boston Society of Civil Engineers was held this evening at 8 o'clock in the Assembly Hall of the Engineers Club, Vice-President William S. Johnson in the chair. One hundred and five members and visitors present.

The reading of the record of the January meeting was, by vote, dispensed with, and it was approved as printed in the February JOURNAL. The Secretary read the record of the special meeting held February 11, 1914, which was approved.

On motion of Mr. Charles R. Gow, the thanks of the Society were voted to the governors of the Engineers Club for their kind invitation to hold the meeting in their Assembly Hall and for their courtesy in extending the privileges of the Club to our members this evening.

Mr. Luis G. Morphy was then introduced and read a paper on the Railroad Improvements at Worcester, Mass., which was illustrated with lantern slides.

A discussion followed the reading of the paper, in which Prof. George F. Swain, Mr. Harrison P. Eddy and others took part. Mr. M. S. Jameson, who was resident engineer on the

work, also gave some interesting details of the construction of the foundations.

Adjourned.

S. E. Tinkham, *Secretary.*

FEBRUARY MEETING OF THE SANITARY SECTION.

Boston, Mass., February 4, 1914. — A special meeting of the Sanitary Section of the Boston Society of Civil Engineers was held this evening at the Engineers Club.

A special dinner was served by the Club, at which 35 members and guests were present.

The meeting was opened at 7.45 o'clock by Chairman Edmund M. Blake. After making announcements regarding the annual March meeting, the Chairman appointed the following members to serve as a Nominating Committee to report at the March meeting nominations for officers and members of the Executive Committee of the Section for the coming year: Edgar S. Dorr, *chairman;* Hector J. Hughes, John W. Howard.

Mr. George A. Carpenter, City Engineer of Pawtucket, presented a very interesting paper on "Sewage Measurement and Automatic Storm Overflow Control at Pawtucket, R. I." This paper described a unique method of measuring and controlling the discharge of sewage from the Pawtucket sewers into the Providence system. The old Pawtucket sand filtration plant was briefly described and the reasons given for abandoning this method of disposing of the sewage. One interesting feature of the controlling device was the use of an old type of Venturi meter register to operate an 18-in. hydraulically operated gate.

Mr. C. G. Richardson gave an illustrated talk on "The Venturi Meter for Measuring Sewage," including certain recently discovered facts concerning the life and professional work of Venturi, and the principles of the design and construction of Venturi meters. Many views were shown illustrating typical installations of meters for measuring both water and sewage.

Following this paper, brief descriptions of measuring devices were given by Messrs. Edward Wright, Jr., Frank A.

Marston, Frank B. Sanborn, and a written discussion from Edwin H. Rogers read by William P. Morse.

It was voted to extend the thanks of the Section to Mr. C. G. Richardson for his courtesy in presenting the paper on Venturi meters.

There were 60 present at the meeting. Adjourned at 10.10 o'clock P.M.

FRANK A. MARSTON, *Clerk*.

APPLICATIONS FOR MEMBERSHIP.

[March 3, 1914.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

BURNES, GEORGE ROBERT, Everett, Mass. (Age 23, b. Salem, Mass.) Graduate of Massachusetts Institute of Technology, 1913, civil engineering course, degree of S.B. June, 1913, to October, 1913, in city engineer's office, Chelsea, Mass.; October, 1913, to date, in Boston office of Concrete Steel Company. Refers to C. F. Allen, W. M. Bailey, L. E. Moore, Dwight Porter and C. M. Spofford.

RICHARDSON, LYLE MERTON, Boston, Mass. (Age 22, b. Mars Hill, Me.) Fourth-year student in civil engineering at Massachusetts Institute of Technology and candidate for graduation in June, 1914. June, 1913, to

October, 1913, transitman and inspector on reservoir for Rumford Falls, Me., Water Works. Refers to C. F. Allen, C. B. Breed, Dwight Porter and C. M. Spofford.

SHAW, ARTHUR LASSELL, Boston, Mass. (Age 26, b. Clinton, Mass.) Graduate of Massachusetts Institute of Technology, 1909, in civil engineering course. September, 1909, to June, 1910, assistant on instructing staff, Civil Eng. Dept., Mass. Inst. of Tech.; July, 1910, to April, 1911, with Boston & Albany R. R. in office of engineer of structures, as draftsman on design, layout and construction of railroad bridges; April, 1911, to date, with Barrows & Breed, Boston, as assistant engineer, engaged in design of steel and concrete buildings and railway structures, studies and estimates of grade-crossing elimination, water-power projects, etc. Refers to H. K. Barrows, C. B. Breed, G. F. Hobson, H. A. Miller, M. W. Rew and E. C. Sherman.

WESTON, CLARENCE McLELLAN, New York, N. Y. (Age 28, b. Starks, Me.) Graduate of University of Maine in civil engineering, class of 1908; work completed for Civil Engineering degree to be granted in June of present year. Summer of 1906 on construction work at East Millinocket, Me.; summer of 1907 on power development surveys for W. H. Sawyer, hydraulic engineer; July, 1908, to January, 1910, with United States Geological Survey as computer and on field work in Nevada and California; February, 1910, to February, 1912, with Sawyer & Moulton as draftsman and assistant field engineer on construction of Aziscohos Dam, April, 1912, to date, with H. S. Ferguson on design of reinforced concrete. Member of Maine Society of Civil Engineers, Refers to H. S. Boardman, H. S. Ferguson, E. G. Lee, W. H. Sawyer and J. W. Tower.

WOODBURY, STANLEY WARD, Haverhill, Mass. (Age 23, b. Haverhill. Mass.) Graduated from Haverhill High School in 1909; is now taking I. C. S. course in civil engineering. October, 1909, to date, with Essex County Engineering Department on a number of highway and bridge construction jobs, also on road surveys and layouts, has done considerable office work. Refers to R. R. Evans, R. A. Hale and A. D. Marble.

EMPLOYMENT BUREAU.

THE Board of Government has established an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and other desiring men capable of filling responsible positions.

At the Society rooms two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

Men Available.

216. Age 22. Graduate of Newton Technical School. Has had two years' experience as mechanical draftsman and six months' experience in tracing and small detail work. Desires position as draftsman. Salary desired, $14 per week.

217. Age 35. Has had sixteen years' experience in general engineering, including topographical, landscape and construction work; was for four years with Fore River Company, of Quincy, laying out foundations, buildings, railroad, crane service, wharves and dredging; at present in charge of preliminary survey for water supply, city of Portsmouth, N. H. Desires position with contractor or landscape architect for general work, location immaterial. Salary desired, $150 per month.

218. Age 33. Educated in Boston public schools, including Mechanic Arts High School; also studied at Massachusetts Institute of Technology. Has had thirteen years' experience, including preliminary surveys, office work and supervision of construction with Massachusetts State Board of Health, Sewer Department of City of Boston, Charles River Basin Commission and Board of Water Supply of New York City; since 1909 has been assistant engineer in charge of section for New York Board of Water Supply. Desires executive engineering position on construction or investigation work. Salary desired dependent upon location and permanency of position offered.

219. Age 23. Graduate of Massachusetts Institute of Technology, 1913, in civil engineering course. Has had about six months' experience in drafting, also slight experience with the transit. Will accept any position in the engineering line. Salary expected dependent upon location and nature of work to be done.

220. Student for one year at Boston Y. M. C. A., course in railroad engineering; for three years at Franklin Union, course in structures. With Boston Elevated Railway Company, as rodman from March, 1904, to April, 1907, and as transitman from April, 1907, to March, 1912; from March, 1912, to June, 1913, with Boston Dwelling House Co., as assistant engineer;

June, 1913, to January, 1914, with Hugh Nawn Contracting Company as assistant engineer; total of ten years' experience on elevated railway, subway and municipal construction work. Salary desired, $100 per month.

LIST OF MEMBERS.

ADDITIONS.

DALTON, THOMAS VINCENT.................23 Allston Sq., Allston, Mass.
REILLY, L. BAYLES..................165 Crawford Street, Roxbury, Mass.

CHANGES OF ADDRESS.

ALDEN, HOWARD K....................2 Fayette Park, Cambridge, Mass.
ALLEN, LAWRENCE H......................34 Avon Way, Quincy, Mass.
BALDWIN, LOAMMI F......................12 Elm Street, Woburn, Mass.
BEACH, THEODORE M.................109 Marion Street, Springfield, Mass.
BIGELOW, JAMES F...................Santa Barbara, Isle of Pines, W. I.
BIGELOW, WILLIAM W..................Everett Chambers, Portland, Me.
DOHERTY, PHILIP J............................St. Johnsbury Center, Vt.
DOTTEN, WILLIAM J......................847 Fellsway, Medford, Mass.
HARRISON, HOWARD G...............438 Shoshone Place, Spokane, Wash.
JOHNSON, GRANVILLE.................78 Devonshire Street, Boston, Mass.
MATAMOROS, LUIS..............San José, Costa Rica, C. A., P. O. B. 295.
PARLIN, RAYMOND W..............59 Highland Place, Fall River, Mass.
RICH, MALCOLM ....Wollaston, Mass.
SANBORN, MORTON F..............................Pleasantville, N. Y.
SARGENT, EZEKIEL C............................Box 26, Quincy, Mass.
SAVILLE, CALEB M................53 Beacon Street, North, Hartford, Conn.
SULLIVAN, WILLIAM F..........................Box 425, Nashua, N. H.
WILLARD, ERNEST C................Close Inn Apartments, Spokane, Wash.

LIBRARY NOTES.

RECENT ADDITIONS TO THE LIBRARY.

U. S. Government Reports.

Annual Report of Coast and Geodetic Survey for 1913.
Anomalies of Gravity. Grove Karl Gilbert.
Circle Quadrangle, Alaska. L. M. Prindle.
Cobalt, Molybdenum, Nickel, etc., in 1912. Frank L. Hess.

Forest Fire Protection by the States.

Lead in 1912. C. E. Siebenthal.

Mineral Products of the United States in 1911 and 1912. E. W. Parker and W. T. Thom.

Mud Lumps at the Mouths of the Mississippi. Eugene Wesley Shaw.

Noatak-Kobuk Region, Alaska. Philip S. Smith.

Phosphate Deposits in Southwestern Virginia. George W. Stose.

Stone Industry in 1912. Ernest F. Burchard.

Supply and Distribution of Cotton, 1913.

Triangulation on Coast of Texas from Sabine Pass to Corpus Christi Bay. Charles A. Mourhess.

Water-Supply Papers 295, 302, 303 and 319.

Zinc and Cadmium in 1912. C. E. Siebenthal.

State Reports.

Massachusetts. Annual Report of Public Service Commission for 1913. (Advance copy.)

New York. Specifications for Roads and Pavements, recommended to State Department of Efficiency and Economy, 1913. A. H. Blanchard and Prevost Hubbard. Gift of the authors.

Vermont. Vermont Telephone Rate Case. Gift of H. S. Knowlton.

City and Town Reports.

Fort Wayne, Ind. Report to Citizens' Flood Prevention Committee. A. W. Grosvenor.

New York, N. Y. Preliminary Reports of Metropolitan Sewerage Commission on Disposal of Sewage, 1913–14, Nos. VIII, IX and X.

North Adams, Mass. Annual Report of Departments of Public Works and Engineering for 1913.

Philadelphia, Pa. Annual Report of Bureau of Surveys for 1912.

Pittsburgh, Pa. Maps to accompany Report of Flood Commission, 1911. Gift of Clemens Herschel.

Miscellaneous.

Buff and Buff Manufacturing Company. (The) Buff Transit.

(Le) Bilan d'un Siècle, 6 vols. Alfred Picard. Gift of Clemens Herschel.

Canada, Department of Mines. Austin Brook Iron-bearing District, New Brunswick; Magnetite Occurrences along the Central Ontario Railway, with maps. Both by Einar Lindeman.

Engineering Index for 1913.

Institution of Civil Engineers. Minutes of Proceedings, Vols. 163–185, inclusive; and Vols. 190 to date, inclusive. Gift of Clemens Herschel.

Railway Practice. S. C. Brees. 2d ed., 1838. Gift of W. H. Norris.

Recherches sur la Construction la plus Avantageuse des Digues. Bossut et Viallet. Gift of F. I. Winslow.

(The) Truth about the Railroads. Howard Elliott. Gift of "A lady who takes a great interest in the subject."

Vitruve, 3 vols. Auguste Choisy. Gift of Clemens Herschel.

Among several items listed above, for which we are indebted to Mr. Clemens Herschel, you will note a considerable number of volumes of the Minutes of Proceedings of the Institution of Civil Engineers. These volumes make our file complete from Volume 59 to date, and Mr. Herschel, who is a life member of the Institution, has very generously offered to send to the Society each year, as he receives them, his volumes of these Proceedings. This practical expression of interest in the Society is most encouraging to the committee in its attempts to build up the library, and must be so to the Society at large. Cannot some one put us on the track of Volumes 4 to 58, inclusive, of these Minutes of the Proceedings of the Institution, that we may have a complete file from the beginning?

Our file of the Proceedings of the Engineers' Club of Philadelphia ends with Volume 21, for the year 1904. As this Club is now on our exchange list, we shall receive these proceedings

from now on. Can any of our members aid us in procuring Volumes 22 to 30, inclusive, and Numbers 1 to 4, inclusive, of Volume 31?

We regret to note that some of our members still persist in taking out books without charging them. Some of them return the books; no doubt all of them intend to. Good intentions minus the books, however, are of very little value, and past experience has taught us that such a practice can result only in the loss of books and consequent injury to the library. Moreover, we can see no possible excuse for it, and we earnestly request that it be discontinued. Will the members who have taken out without charging them book 10–3.2–10, Metrical Tables, by Olin H. Landreth, and book 10–3.3–4, New Roadmaster's Assistant, by George H. Paine, kindly return them at once?

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before the 25th of each month.)

United States Government. — NAVY DEPARTMENT. — *Navy Yard, Boston.* — Work is now in progress or new work is contemplated as follows:

A 2 000 000-gallon fuel oil tank is now under construction. Pipe lines and pump house with control system for same are to be constructed.

Central heating plant, Naval Hospital, Chelsea, to be constructed. Building to be erected by Yard labor.

Building slip and launching ways for construction of naval vessels, to be designed and built in the very near future.

Commonwealth of Massachusetts. — METROPOLITAN PARK COMMISSION. — *Woburn Parkway.* — Work of construction of Woburn Parkway is in progress.

Charles River Reservation, Lower Basin. — Work of construction of retaining wall along Broad Canal on property of Horgan Estate is in progress.

Massachusetts Highway Commission. — Work is in progress on the so-called Revere Traffic Road in Revere, between Revere St. and the Saugus River Bridge of the Metropolitan Park Commission.

Work is also in progress in the construction of a 3-span reinforced-concrete arch bridge, at Point Independence, Wareham, Mass. The abutments and piers are completed, and the arches are to be made when the weather is suitable.

METROPOLITAN WATER AND SEWERAGE BOARD. — *Sewerage Works.* — Work on Section 69, new Mystic Sewer, at Winchester, has recently been started.

Boston Transit Commission. — *Boylston Street Subway.* — The Boylston Street Subway extends from Kenmore St. near the intersection of Commonwealth Ave. and Beacon St. to the southwest corner of the Common near Park Sq., a distance of about 8 000 ft. The subway is completed except for a small portion of the Massachusetts Ave. station, the Dartmouth St. lobby of the Copley Sq. station and the connection with the Tremont St. Subway near Park Sq. Work is in progress at all of these places. Work on the interior finish of the two stations is also in progress. The Boston Elevated Ry. Co. is engaged in installing duct lines, lighting conduits, etc.

Dorchester Tunnel. — Section B includes the proposed station in Summer St., which will extend from near Washington St. east to Arch St. About three fourths of the roof is in place and the earth core below is being excavated. Work is also progressing at the junction of the new station with the Summer station of the Washington St. Tunnel. New manholes, pipes and conduits are being laid over the roof in advance of the backfilling.

Section C is located in Summer St., and extends from near Arch St. to Dewey Sq., a distance of about 1 018 ft. About two thirds of its length is to be built by tunneling. The structure is to be mainly of reinforced concrete. Work is in progress in the open-cut section between Otis and Devonshire Sts.

East Boston Tunnel Extension. — Section G extends in Court St. from the easterly side of Cornhill westerly to Stoddard

St. The structural work from Brattle St. to Stoddard St. is practically completed. Between Brattle St. and Cornhill, the construction of a part of the station under and near the present Scollay Sq. station is in progress. Isaac Blair & Company, Inc., is the contractor.

Section J extends from Staniford St. to North Russell St. The incline in Cambridge St. between Chambers and North Russell Sts. has been built. Excavation is proceeding between Staniford and Chambers Sts. The walls of the tunnel are partly built and a considerable portion of the roof has been placed in this vicinity.

The Fore River Shipbuilding Co., Quincy, Mass., has the following new work in progress:

U. S. Battleship *Nevada*.

U. S. Submarine Tender *Fulton*.

Ten U. S. submarine boats.

U. S. Torpedo Boat Destroyers *Cushing* and *No. 57*.

General cargo steamers *Atlantic* and *Pacific*, for the Emery Construction Company.

Vol. I | APRIL, 1914 | No. 4

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

PAPERS IN THIS NUMBER.

Discussion of "Boston Foundations."

Address at the Annual Meeting, March 18, 1914. Frederic H. Fay.

Current Discussions.

	Paper.	Author.	Published.	Discussion Closes.
1.	"Boston Foundations."	J. R. Worcester.	Jan.	May 10.
2.	"Main Drainage Works Proposed for New York."	Geo. A. Soper.	Feb.	April 15.
3.	"Fall River Bridge."	J. W. Rollins.	Feb.	April 15.
4.	"Engineering Lessons from the Ohio Floods."	John W. Alford.	March.	May 15.
5.	"Bitulithic Pavement and Warrenite Roadway."	G. H. Perkins.	March.	May 15.
6.	"Cost Accounting on Construction Work."	Leslie H. Allen.	March.	May 15.

Note. At the request of a number of members of the Society the date of closing the discussion of "Boston Foundations" has been extended to May 10.

REGULAR MEETING.

A regular meeting of the Boston Society of Civil Engineers will be held on Wednesday, April 15, 1914, at 7.45 o'clock P.M., in

CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Business of the Meeting. — To consider the recommendation of the Board of Government, made in its report submitted at the annual meeting, regarding the use of a portion of the income from the Permanent Fund for current expenses.

Mr. F. H. Fay offers the following amendments to By-Law 9: Add after the word "fund" at the end of the first sentence the words, "provided, however, that the income of the fund, or any portion thereof, in any year may be used for current expenses of that year, at the discretion of the Board of Government"; and insert in the second sentence after the word "money" the words "other than income above specified." The By-Law will then read: PERMANENT FUND. — There shall be a fund called the Permanent Fund, to which shall be added all money received for entrance fees and all income from investments of the fund, *provided, however, that the income of the fund, or any portion thereof, in any year may be used for current expenses of that year, at the discretion of the Board of Government.* No money, *other than income above specified,* shall be appropriated from the fund except by a two-thirds vote at two successive regular meetings. Any such appropriation or any part thereof not used within three years shall be returned to the fund.

Mr. J. S. Miller, Jr., assistant chief chemist of the Barber Asphalt Paving Company, will give a lecture illustrated by lantern slides and motion pictures entitled, "Asphalt and Asphaltic Street and Road Construction."

S. E. TINKHAM, *Secretary.*

MINUTES OF MEETINGS.

BOSTON, February 25, 1914. — A special meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order by the President, Mr. Frederic H. Fay, at 8.15 o'clock. There were 45 members and visitors present.

The meeting was devoted to a discussion of Mr. J. R. Worcester's paper on "Boston Foundations," printed in the January number of the Journal.

Among those who took part in the discussion were the following: Charles R. Gow, Charles T. Main, Henry F. Bryant, L. B. Manley, A. O. Doane, E. W. Howe, J. E. Carty, J. R. Worcester and T. W. Clarke.

At 9.45 o'clock the meeting adjourned.

S. E. Tinkham, *Secretary.*

Boston, Mass., March 18, 1914. — The sixty-sixth annual meeting of the Boston Society of Civil Engineers was held at the Boston City Club, 9 Beacon Street, Boston, at 12.30 o'clock p.m., President Frederic H. Fay in the chair.

The reading of the record of the regular meeting held on February 18 was by vote dispensed with, and it was approved as printed in the March Journal. The Secretary read the record of the special meeting held February 25, and by vote it was approved.

The Secretary reported for the Board of Government that the following candidates had been elected to membership in the grades named:

Member — August Fredrik Bildt.
Junior — Miles Erskine Langley.

The Secretary read the annual report of the Board of Government, and by vote it was accepted.

On motion of Prof. C. F. Allen, it was voted, That the recommendation of the Board of Government regarding the Permanent Fund be made a part of the business of the next regular meeting of the Society.

The Secretary read his annual report, and by vote it was accepted.

The Treasurer presented and read his annual report, omitting the tables. From these tables he gave brief abstracts. By vote the report was accepted.

The Librarian read the report of the Committee on the Library, and by vote the report was accepted and the recom-

mendation appropriating $60 for the purchase of current engineering books was adopted.

Mr. Charles R. Gow, for the Committee on Excursions, presented a brief report which was accepted.

On motion of Mr. Bryant it was voted to refer to the Board of Government the question of appointing the special committees of the Society, with full power to act.

The Secretary read a letter from Past President John R. Freeman, in which he stated that he had shipped to the Society one of the Bausch & Lomb convertible balopticans, together with an aluminum screen and tubular stand for supporting the apparatus. He stated that this baloptican he believed to be the most complete apparatus in the market, as it would permit post cards, mineralogical specimens, or anything of that sort, including photographs up to eight inches square, to be shown by opaque projection.

On motion of Mr. C. W. Sherman, the thanks of the Society were voted to Mr. Freeman for his generous gift.

Past President E. W. Howe, at the request of the President, presented in the name of the Society the Desmond FitzGerald medal for the year 1913 to David Alfred Hartwell, for his paper entitled, "The Fitchburg, Mass., Intercepting Sewer." Mr. Hartwell in accepting the medal expressed his deep appreciation of the honor conferred upon him in the award of the medal.

Mr. R. E. Curtis spoke briefly of the joint engineering meetings which had been held in Boston for several years past, and suggested that greater coöperation of the various engineering organizations in Boston would add very much to the advancement of the profession. On motion of Mr. Bryant, it was voted that the Board of Government be requested to appoint a committee of three to consider means for further coöperation among the various societies.

The retiring President, Mr. Frederic H. Fay, then delivered an address, which will be found on page 249 of this number of the Journal.

The tellers of election appointed by the President, Messrs. Edward W. Howe and Harry F. Sawtelle, submitted their report giving the result of the letter ballot, and in accordance with this

report the President announced that the following officers had been elected:

President — Harrison P. Eddy.

Vice-President (for two years) — Richard A. Hale.

Secretary — S. Everett Tinkham.

Treasurer — Charles W. Sherman.

Directors (for two years) — Charles M. Allen and Leonard C. Wason.

The President then introduced the President-elect, Mr. Harrison P. Eddy, who thanked the members of the Society for the honor they had bestowed on him in this election, and promised his best efforts, with the aid of the other officers selected, to advance the interests of the Society.

The members then adjourned to the auditorium of the City Club, where members and guests to the number of 118 sat down to the thirty-second annual dinner.

After the dinner Mr. Nelson P. Lewis, chief engineer, Board of Estimate and Apportionment of the City of New York, gave an exceedingly interesting address, illustrated with lantern slides, on "City Planning from the Standpoint of the Engineer."

In the evening the usual "Smoker" was held in the auditorium, the attendance being about 250. The gathering was of the same character as in former years, and in addition to music by an orchestra and songs by members, entertainment was furnished by Mr. Chevalier, magician, Mr. Bradley, singer, and Mr. Martin in Italian dialect.

S. E. Tinkham, *Secretary.*

ANNUAL MEETING OF THE SANITARY SECTION.

Boston, Mass., March 4, 1914. — The annual meeting of the Sanitary Section, Boston Society of Civil Engineers, was held this evening at the Engineers Club.

A special dinner was served in the main dining room of the Club at 6.15 o'clock, to 49 members and guests. As this was the tenth annual meeting of the Section, special features were introduced during the dinner, such as stories and short speeches

by various members, which helped to make the dinner a very enjoyable one.

Mr. E. S. Dorr gave a few words of welcome to the guest of the evening, Mr. George S. Webster, of Philadelphia, to which Mr. Webster responded. Several of the past chairmen were called upon, — Messrs. George C. Whipple, George A. Carpenter and Harrison P. Eddy, — as well as other members. A choice collection of stories and songs were given by Mr. W. B. C. Fox, assisted by the chairman at the piano, which added greatly to the fun.

The annual business meeting of the Sanitary Section was opened in the Assembly Hall at 7.30 o'clock, by Chairman Edmund M. Blake.

The minutes of the December and January meetings were approved as printed in the *Bulletin* and JOURNAL of the Society respectively.

The minutes of the February meeting were read by the Clerk and approved as read.

The Committee on Rainfall and Run-off presented their final report, covering several years' work and embodying the data relating to the measurement of rainfall, run-off, the results of gagings, a bibliography, and other information collected by the committee.

On motion of C. W. Sherman, seconded by F. B. Sanborn, it was voted that the report be accepted and the committee discharged.

H. P. Eddy moved that the report be referred to the Executive Committee of the Section for such action as they should decide upon. The motion was seconded by W. S. Johnson and carried.

It was suggested that the report be printed in the JOURNAL and that thereafter a meeting be arranged for discussion of the subject. In order to give the members a brief knowledge of the points covered by the report, Mr. George A. Carpenter, chairman of the committee, gave a short résumé.

The report of the Committee on Sewerage Statistics was read by Almon L. Fales, chairman. A brief discussion was presented by G. A. Carpenter.

On motion of G. C. Whipple, seconded by G. A. Carpenter, it was voted to accept the report and refer it to the Executive Committee with the suggestion that it be printed in the JOURNAL and discussed at some future meeting; also, that a copy of the report when printed be sent to the United States Census Bureau by the Clerk.

The report of the Executive Committee for the past year was then read by the Clerk.

It was moved by W. S. Johnson, seconded by F. P. Stearns, that the report be accepted and placed on file, and it was so voted.

H. P. Eddy made a motion, seconded by E. S. Dorr, that the report be referred to the incoming Executive Committee to consider the suggestions offered, and the motion was carried.

The report of the informal nominating committee was presented by E. S. Dorr, chairman, with nominations for officers and members of the Executive Committee for the ensuing year, as follows:

Chairman, Bertram Brewer.

Vice-Chairman, Elliott R. B. Allardice.

Clerk, Frank A. Marston.

Executive Committee (additional members): David A. Hartwell, Dwight Porter, Edmund M. Blake.

No further nominations were offered, and on motion of C. W. Sherman, duly seconded, it was voted to close nominations.

C. W. Sherman then moved that Mr. Dorr be instructed to cast one ballot for the officers and members of the Executive Committee as nominated. It was seconded and duly carried. Mr. Dorr cast a ballot as instructed, and the officers and members of the Executive Committee as above stated were declared elected.

As there was no further business to come before the meeting at that time, a short intermission was declared before taking up the literary program.

Shortly after 8 o'clock, the Chairman introduced, as the speaker of the evening, Mr. George S. Webster, chief engineer and surveyor of the Bureau of Surveys of Philadelphia, who presented a very interesting and instructive paper on "The

Collection and Treatment of Sewage in Their Relation to the City of Philadelphia." Mr. Webster described the proposed plans for intercepting and treating the sewage of the city before its final disposal by discharge into the rivers. He also showed the similarity between the proposed plans and those now in operation under similar conditions in such foreign cities as Dresden, Berlin, Frankfort, London, Birmingham and others. The recently completed sewage treatment plant at Pennypack Creek, Philadelphia, was described in some detail. The paper was well illustrated by lantern slides, and aroused considerable interest.

Mr. Frederick P. Stearns discussed the paper and referred to the oxidizing action of river water and the self-purification of streams as illustrated at Pittsburg, Pa., and the Chicago Drainage Canal.

Mr. Frederick H. Fay, president of the Boston Society of Civil Engineers, spoke on behalf of the Society in offering congratulations to the Section on the high standing which had been maintained during the past ten years and on the character of the papers, which he considered were worthy of a national society.

It was voted to extend the thanks of the Section to Mr. Webster for his courtesy in presenting the paper.

Chairman Edmund M. Blake spoke briefly in appreciation of the assistance accorded him by the members during the past year. Mr. Webster also spoke of his interest in the work the Section was doing.

On motion of G. A. Carpenter, it was voted to extend the retiring chairman, Mr. Edmund M. Blake, a vote of appreciation for his earnest efforts in behalf of the Section which had contributed largely toward the success of the past season.

The newly-elected chairman, Mr. Bertram Brewer, was then introduced.

There were 80 present at the meeting. Adjourned at 9.50 o'clock.

FRANK A. MARSTON, *Clerk.*

ANNUAL REPORTS

Annual Report of the Board of Government for the Year 1913–14.

Boston, Mass., March 18, 1914.

To the Members of the Boston Society of Civil Engineers:

In compliance with the requirements of the Constitution, the Board of Government submits its report for the year ending March 18, 1914.

At the last annual meeting the total membership of the Society was 823, of whom 754 were members, 28 juniors, 2 honorary members, 23 associates and 16 were members of the Sanitary Section only.

During the year the Society has lost a total of 24 members, 16 by resignation, 5 by forfeiture of membership for non-payment of dues, and 3 have died.

There has been added to the Society during the year a total of 38 members of all grades; 37 have been elected and one has been reinstated; 4 juniors and one member of the Sanitary Section have been transferred to the grade of member.

The present membership of the Society consists of 2 honorary members, 762 members, 37 juniors, 22 associates and 14 members of the Sanitary Section only, make a total membership of 837.

The record of deaths during the year is —

George Blinn Francis, past president, died June 9, 1913.
George A. Nelson, died June 3, 1913.
Edward A. Haskell, died August 24, 1913.

As required under By-Law 8, the Board reports that for good and sufficient reasons it has remitted this year the dues of eleven members of the Society. Since this action of the Board the dues from three of these members have been received, and of the remainder more than half are so far away that there has not been sufficient time to receive a reply to the last notice sent them.

Ten regular and three special meetings have been held during the year. The average attendance at the meetings was 123, as against 175 last year, the largest being 300 and the smallest 36.

The following papers and talks have been given at the meetings:

March 19, 1913. — J. Waldo Smith, "Some Features of the Contracts, Specifications and Construction of the Catskill Water Supply for the City of New York." (Illustrated.)

April 16, 1913. — James H. Sullivan, "Paving Progress in Greater Boston," with discussion.

May 13, 1913 (special students' meeting). — James W. Rollins, "Reminiscences of an Engineer."

May 21, 1913. — Charles M. Spofford, "The Technology Summer Surveying Camp at East Machias, Maine." (Illustrated.)

June 25, 1913. — Charles B. Breed, "Elimination of Grade Crossings at Lynn, Mass." (Illustrated.)

September 17, 1913. — Leonard C. Wason, "The Problems of a Contractor." (Illustrated.)

October 15, 1913. — John L. Howard, "The Work of the Directors of the Port of Boston." (Illustrated.)

November 19, 1913. — John W. Alvord, of Chicago, "Engineering Lessons from the Ohio Floods." (Illustrated.)

December 17, 1913. — James W. Rollins, "Construction and Repairs of the Brightman Street Bridge, Fall River." (Illustrated.) G. H. Perkins, superintendent of refinery of Warren Brothers Company, "Bitulithic Pavement and Warrenite Roadway." (Illustrated.)

January 28, 1914. — Joseph R. Worcester, "Boston Foundations," with discussion. (Illustrated.)

February 11, 1914 (special meeting). — G. F. Ahlbrandt, metallurgical engineer, "Pure Iron versus Steel." (Illustrated.)

February 18, 1914. Luis G. Morphy, "Railroad Improvements at Worcester, Mass." (Illustrated.)

February 25, 1914 (special meeting). — Discussion on "Boston Foundations."

The Sanitary Section of the Society has held four meetings during the year, with an average attendance of 82. The following papers have been presented at the meetings of the Section:

March 5, 1913. — Dr. Shaoching H. Chuan, "A Glimpse of Tibet."

December 3, 1913. — Dr. George A. Soper, "The Main Drainage Works Proposed for New York City."

January 7, 1914. — Charles H. Paul, "The Arrowrock Dam of the United States Reclamation Service." (Illustrated.)

February 4, 1914. — George A. Carpenter, "Sewage Measurement and Automatic Storm Overflow Control at Pawtucket, R. I." C. G. Richardson, "The Venturi Meter for Measuring Sewage." (Illustrated.)

On May 13, 1913, for the third time, the students in the engineering courses at Harvard, Tufts and the Institute of Technology were the guests of the Society at a special meeting held at the Boston City Club. Past President James W. Rollins gave an illustrated talk on "Reminiscences of an Engineer." The attendance was about 300.

The plan of holding joint meetings with members of the American Society of Mechanical Engineers and the Boston Section of the American Institute of Electrical Engineers has continued during the past year, each organization arranging the program for one meeting.

The Board of Government has adopted the recommendation of the committee appointed to award the Desmond FitzGerald medal, and announces that it will be given this year for the paper entitled, "The Fitchburg, Mass., Intercepting Sewer," by David A. Hartwell, read before the Sanitary Section February 5, 1913.

The work of rearranging and cataloguing the library had progressed so far by the first of July last that the Assistant Librarian was able to attend to the clerical work of the Secretary in addition to the library work, and the services of a stenographer and custodian were dispensed with.

A slight change was made in the officers of the Society at the beginning of the year, by which the Secretary was made Librarian, all the executive work of the Society being thus placed in his charge, and a small saving in the amount paid for salaries being made.

During the year the Board has made some additions to the furnishings

of the Society rooms, the cost being paid from the special appropriation of $2 000, made from the Permanent Fund in November, 1912; but the total amount paid from the appropriation to date has not exceeded the $1 200 originally estimated for the furnishing of the rooms.

As a result of the letter-ballot canvassed at the regular meeting of June 25, 1913, the Society withdrew from membership in the Association of Engineering Societies on December 31, 1913, and with the issue for January, 1914, the Society began the publication of its own transactions under the title of the JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS. Mr. Edward C. Sherman, a member of the Society, has been elected Editor of the JOURNAL, and the Society is to be congratulated on the excellent manner in which he has issued the first numbers of the JOURNAL. The high standard which has been set in the initial number, and the valuable material now on hand and in preparation for publication in succeeding numbers, give assurance that the first volume of the JOURNAL will be a credit to the Society.

The Board is of the opinion that the time has arrived when a readjustment of the financial policy of the Society is desirable. The most rigid economy is now necessary at all times to avoid the probability of a deficit at the close of the fiscal year, with the result that the Board is often seriously restricted in the adoption of policies which it considers would be advantageous to the Society's welfare.

That this condition should exist at a time when the Society is essentially financially prosperous is explained by the presence in our By-Laws of provisions whereby certain portions of the yearly income are required to be added to the Permanent Fund, from which, at present, the Society derives no benefit. The yearly accretion from interest now added to this fund as shown by the report of the Treasurer is in excess of fifteen hundred dollars, and is rapidly growing.

In general it may be said that a loss results in current funds on account of each member's first year in the Society. This is a result of that provision of the By-Laws which requires that all entrance fees shall pass to the Permanent Fund and that the dues for the initial year shall be reduced by fifty per cent. In other words, a great influx of new members in a given year is a handicap to the financial operations of the Society's affairs rather than a benefit, as it obviously should be.

The Board believes that this anomalous condition should be corrected by a provision which would permit the Board of Government, in its discretion, to apply to legitimate current expenses in any year, such portion of the income from the Permanent Fund for that year as it may deem necessary. Such a provision would of course necessitate an amendment to the present By-Laws, and the Board recommends that such an amendment be made.

For the Board of Government,

FREDERIC H. FAY, *President.*

Report of the Treasurer.

Boston, March 18, 1914.

To the Boston Society of Civil Engineers:

Your Treasurer submits his report for the year ending March 18, 1914.

The data are contained in the appended tabular statements: Table 1, profit and loss statements for four years; Table 2, comparative balance sheets; Table 3, investment of the Permanent Fund; Table 4, statement of cash balance; and Table 5, growth of the Permanent Fund.

The income applicable to current expenses has been $7 898.34 — about $400 more than for the previous year. The expenses have been $8 672.78, or about $1 800 greater than for last year, showing a net loss for the year of $774.44. The fact that there is a loss is due wholly to the extraordinary character of the January issue of the Journal, resulting in a very large cost for illustrations. Under ordinary conditions in this respect, the year's accounts would have shown a very close balance.

The expense of issuing two numbers of the Journal, $1,473.53, affords no basis for estimating the ordinary cost of our magazine, since the excess cost of the January issue and the expenses of making a start are included. If these extraordinary expenses were eliminated, the account would probably be reduced by about $800.

It is worthy of note that although the income for advertising has been less than $1 000, the annual value of the advertising contracts now in force is nearly $1 600, indicating the appreciation of our new Journal as an advertising medium, as well as the work which has been done in soliciting advertising.

The best estimate which it is possible to make at this time indicates receipts for next year of $8 400, and expenses of $8 000, which would leave a balance of $400 for unforeseen expenses.

There has been added to the Permanent Fund during the year, $1 930.45, or about $30 more than for the preceding year. There has been an increase of over $200 from interest, and a decrease of about $200 in the amount of entrance fees. These fees have been less in amount than for five or six years past.

There has been expended during the year from the appropriation for improving and furnishing the rooms, $199.94, leaving $851.46 unexpended.

The present value of the Permanent Fund, excluding this appropriation, is $31 864.29. This statement is based upon the "book values" of securities as carried upon the Society's books, and represents the cost of the bonds and stocks with but one or two exceptions. The values are somewhat higher than present market values, and if the latter were used, the value of the Permanent Fund would be about $700 less. The book values are believed to represent more nearly the normal values of the securities than the present market values. No account has been taken in these statements of the accrued interest upon bonds, the value of which increases slightly from year to year, but not enough to affect the comparisons or general statements made above.

Respectfully submitted,

Charles W. Sherman, *Treasurer.*

TABLE I. — PROFIT AND LOSS STATEMENTS.

	1910–11.	1911–12.	1912–13.	1913–14.
Income:				
Members' Dues.	$4 567.00	$6 448.50	$6 443.00	**$6 671.59**
Advertisements.	1 004.50	984.50	938.50	**973.00**
Sales of JOURNAL.	4.50	8.25	9.40	**33.55**
Library Fines.	4.75	5.56	7.28	**8.01**
Interest.	10.47	22.81	95.30	**159.25**
Excursion Committee.	. . . .	. . . .	. . . .	**52.94**
Total Current Income. . . .	$5 591.22	$7 469.62	$7 493.48	**$7 898.34**
Entrance Fees.	$945.00	$410.00	$525.00	**$315.00**
Contributions.	200.00	100.00	100.00	**100.00**
Interest.	1 231.78	1 301.72	1 277.70	**1 515.45**
Total Income Permanent Fund.	$2 376.78	$1 811.72	$1 902.70	**$1 930.45**
Appropriation from Permanent Fund.	. . . .	. . . .	$2 000.00	. . . .
Balance from Previous Appropriations.	. . . .	. . . .	. . . .	**$1 051.40**
Total Available from Appropriations.	. . . .	. . . .	$2 000.00	**$1 051.40**
Surplus Account.	$1.50	. . . .	. . . .	. . . . . .
Deficit for the year (Current Funds).	940.26	. . . .	. . . .	**$774.44**
	$8 909.76	$9 281.34	$11 396.18	**$11 654.63**
Expense:				
Association Eng. Societies. .	$1 912.62	$2 010.00	$2 026.25	**$1 564.38**
Bulletin.	*	763.83	783.49	**687.75**
JOURNAL B. S. C. E. (incl. Editor's salary).	. . . .	. . . .	. . . .	**1 473.53**
Printing, Postage, Stationery,	1 770.96	593.16	644.46	**838.54**
Rent (net).	856.74	920.00	1 320.75	**1 632.00**
Light.	53.76	49.68	70.31	**62.38**
Salaries (except Editor). . . .	1 007.00	992.00	1 248.50	**1 358.00**
Reporting.	282.00	68.00	20.50	**41.00**
Stereopticon.	180.00	130.00	134.50	**107.50**
Books.	72.10	40.53	52.11	**33.10**
Binding.	81.20	169.30	81.15	**197.25**
Periodicals.	31.00	47.00	34.25	**58.15**
Incidentals and Repairs. . . .	79.45	84.94	87.77	**62.40**
Insurance.	26.38	26.38	26.38	**41.87**
Telephone.	59.82	65.24	66.27	**50.82**
Sanitary Section Incidentals,	45.00	14.24	22.55	**64.90**
Annual Meeting and Dinner,	43.45	220.82	73.09	**73.38**
Furniture.	31.50	34.25	2.50	. . . .
Navigation Congress.	. . . .	. . . .	20.00	**20.00**
Students' Meeting.	. . . .	. . . .	154.50	**206.48**
Catering.	. . . .	. . . .	. . . .	**45.00**
Excursions.	. . . .	. . . .	. . . .	**38.00**
Lantern Slides.	. . . .	. . . .	. . . .	**16.35**
Total Current Expense. . .	$6 532.98	$6 229.37	$6 869.33	**$8 672.78**

* Included in Printing, Postage, etc.

	1910–11.	1911–12.	1912–13.	1913–14.
Brought forward	$6 532.98	$6 229.37	$6 869.33	**$8 672.78**
Furniture	....	....	$573.15	**$149.50**
Alterations in Rooms	....	....	375.45	**50.44**
Total expended from Appropriations	....	....	$948.60	**$199.94**
Permanent Fund increase	$2 376.78	$1 811.72	$1 902.70	**$1 930.45**
Unexpended Balance of Appropriation	....	....	1 051.40	**$851.46**
Increase for the year, Current Funds	....	1 240.25	624.15	....
	$8 909.76	$9 281.34	$11 396.18	**$11 654.63**

NOTES ON TABLE 1.

Dues.	Received from Secretary	$6 651.59
	Deduct 1914–15 dues in advance	58.00
		$6 593.59
	Add dues paid in advance last year	78.00
	Total Current Dues	$6 671.59
Rent.	Received from Secretary, rent paid by subtenants, as follows:	
	Hersey Mfg. Co.	$500.00
	N. E. W. W. Assn.	400.00
	N. E. Assn. Gas. Engrs.	100.00
		$1 000.00

The gross rent for the Society's rooms amounts to $2 475 per year. In addition $15 is paid for the use of the hall at each meeting. The rent paid for a hall for the Sanitary Section has been entered under the heading of "Sanitary Section" and not as rent.

TABLE 2. — COMPARATIVE BALANCE SHEETS.

Assets:	March 20, 1912.	March 19, 1913.	March 18, 1914.
Cash	$1 033.27	$353.26	$119.41
Bonds	22 975.50	26 615.50	27 605.50
Stocks	....	....	1 950.00
Coöperative Banks	6 667.83	5 315.80	3 545.72
Savings Banks	132.21	....	....
Accounts Receivable (rent)	145.83	145.83	145.83
Library	7 500.00	7 500.00	7 500.00
Furniture	600.00	1 175.65	1 325.15
	$39 054.64	$41 106.04	$42 911.61

Liabilities:	March 20, 1912.	March 19, 1913.	March 18, 1914.
Permanent Fund	$30 031.14	$29 933.84	$31 864.29
Unexpended Appropriations	....	1 051.40	851.46
Current Funds	686.00	1 310.15	535.71
Accounts Payable	237.50	135.00	115.00
Surplus	8 100.00	8 675.65	8 825.15
	$39 054.64	$41 106.04	$42 191.61

Table 3. — Investment of Permanent Fund, March 18, 1914.

Bonds.	Par Value.	Cost.	Present Market Value.	Value as Carried on Books.
Am. Tel. & Tel. Co. col. tr. 4%, 1929	$3 000.00	$2 328.75	$2 662.50	$2 737.50
Republican Valley R. R. 6%, 1919	600.00	616.50	612.00	618.00
Union El. Lt. & Pr. Co. 5%, 1932	2 000.00	2 050.00	2 020.00	2 050.00
Blackstone Valley Gas & Elec. Co., 5%, 1939	2 000.00	1 995.00	1 980.00	1 995.00
Dayton Gas Co. 5%, 1930	2 000.00	2 000.00	1 940.00	2 000.00
Milford & Uxbridge St. Ry. 5%, 1918	3 000.00	2 942.50	2 940.00	2 942.50
Railway & Light Securities Co. 5%, 1939	3 000.00	3 000.00	2 910.00	3 000.00
Superior Water, Lt. & Pr. Co. 4%, 1931	3 000.00	2 505.00	2 460.00	2 505.00
Wheeling Electric Co. 5%, 1941,	3 000.00	2 895.00	2 820.00	2 895.00
Economy Light & Power Co. 5%, 1956	1 000.00	990.00	960.00	990.00
Tampa Electric Co. 5%, 1933	2 000.00	2 000.00	1 960.00	2 000.00
Galveston-Houston Elec. Ry. 5%, 1954	2 000.00	1 940.00	1 900.00	1 940.00
Northern Texas Elec. Co. 5%, 1940	2 000.00	1 932.50	1 880.00	1 932.50
	$28 600.00	$27 195.25	$27 044.50	$27 605.50
Stocks.				
Am. Tel. & Tel. Co.	1 500.00	1 950.00	1 807.50	1 950.00
	$30 100.00	$29 145.25	$28 852.00	$29 555.50

Co-operative Banks:	
25 shares Merchants Coöperative Bank	2 392.27
25 shares Volunteer Coöperative Bank	709.85
25 shares Watertown Coöperative Bank	443.60
	$33 101.22
Cash:	
(Overdraft — borrowed from Current Funds and Appropriation)	− 1 236.93
Total Value of Permanent Fund	$31 864.29

TABLE 4. — STATEMENT OF CASH BALANCE, MARCH 18, 1914.

Value of Current Funds	$535.71
Add Accounts Payable	115.00
	$650.71
Deduct accounts receivable	145.83
Cash on hand, Current Funds	$504.88
Unexpended Balance of Appropriation for Improving and Furnishing Rooms	851.46
	$1 356.34
Permanent Fund, cash overdraft	1 236.93
Total cash on hand	$119.41

TABLE 5. — GROWTH OF THE PERMANENT FUND.

Year.	Value of Permanent Fund.	Remarks.
1882	$1 200.00	
1883	1 385.00	
1884	1 497.00	
1885	1 732.53	
1886	2 159.19	
1887	2 496.56	Spent for bookcases from Permanent Fund, $80.63.
1888	2 572.56	$200 appropriated from Permanent Fund to current funds.
1889	2 921.06	
1890	2 988.12	
1891	3 482.87	
1892	3 928.78	
1893	4 584.80	$200 appropriated from current funds to Permanent Fund.
1894	5 098.40	
1895	5 865.56	
1896	6 640.21	
1897	7 599.38	
1898	8 423.01	
1899	9 252.91	
1900	10 010.38	
1901	12 787.55	$2 017.50 appropriated from current funds to Permanent Fund.
1902	13 650.74	
1903	14 998.74	$500 ditto.
1904	16 080.54	
1905	17 613.75	
1906	18 813.30	
1907	20 058.27	
1908	22 455.02	
1909	24 441.25	
1910	25 979.64	
1911	28 219.42	
1912	30 031.14	
1913	30 985.24*	$2 000.00 appropriated from Permanent Fund for alterating and furnishing rooms, but only $948.60 spent up to date of report.
1914	32 715.75*	$199.94 expended from appropriation.

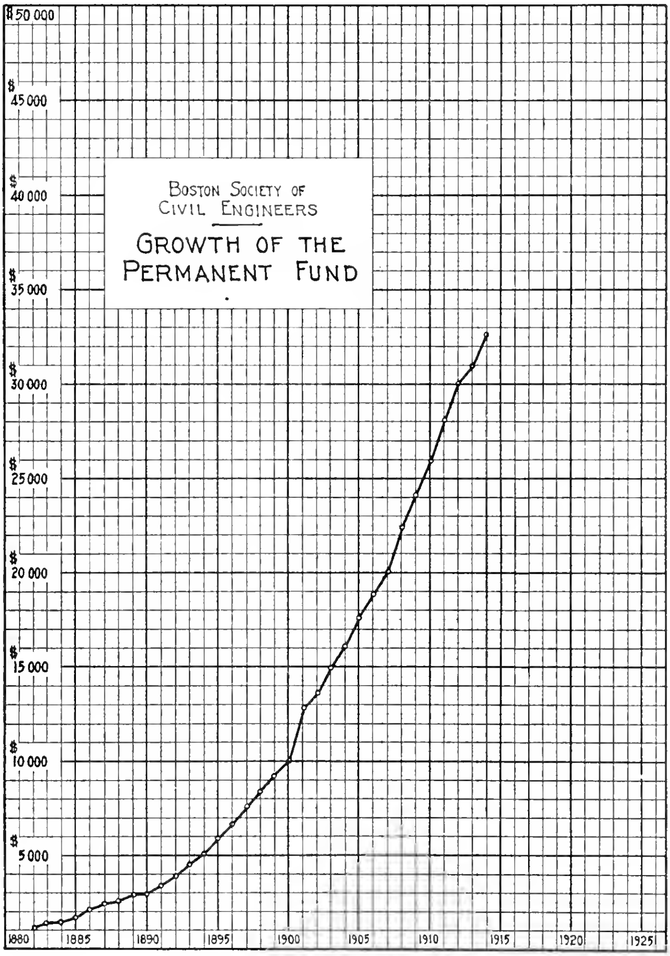
* Includes unexpended balance of appropriation.

NOTES ON TABLE 5.

The Permanent Fund was established by a vote passed at the annual meeting, March 15, 1882, as follows:

" *Voted*, that the income of the invested funds and the money received from entrance fees be added to a permanent fund and not used for current expenses."

At the time this vote was passed the Society had funds to the amount of $1 200 par value invested in two $600 railroad bonds. It should be noted that



the vote does not specifically devote these bonds to a permanent fund, but merely the income of the invested funds, and the money received from the entrance fees. Nevertheless it has been interpreted to mean that the $1 200 was appropriated as the nucleus of the Permanent Fund, to which the income of the fund, and the entrance fees, were to be added.

In examining the figures in Table 5, it should be borne in mind that previous to 1911, the value of the Permanent Fund has been made up to include all investments at par. As nearly all of the investments were bought at less than par, and when they have been resold have also been usually sold at less than par, this has some times resulted in anomalous apparent gains or losses in the value of the Permanent Fund.

The growth of the fund is also shown graphically by the accompanying diagram.

Report of the Auditing Committee.

Boston, Mass., March 17, 1914.

We hereby certify that we have this day examined the books and records of the Treasurer of the Boston Society of Civil Engineers for the year 1913–14; that all receipts are properly accounted for and that there are proper vouchers for all expenditures.

We have also examined the securities and investments of the Society's funds, have verified and compared same with the books and found them all accounted for and properly carried.

We have compared the financial statement of the Treasurer with the books and find it to be correct.

Robert Spurr Weston,
John N. Ferguson,
Directors.

Annual Report of the Secretary, 1913–14.

Boston, Mass., March 18, 1914.

S. Everett Tinkham, Secretary, *in account with the* Boston Society of Civil Engineers. *Dr.*

For cash received during the year ending March 18, 1914, as follows:

From entrance fees, new members and transfers:

21 members . . . . . at $10 =	$210.00		
16 juniors . . . . . at 5 =	80.00		
4 juniors transferred to members . . . . . at 5 =	20.00		
1 Sanitary Section member transferred to member	5.00		
Total from entrance fees		$315.00	

From annual dues for 1913–14, including dues from new members	$6 566.59	
From back dues	27.00	
From dues for 1914–15	58.00	
Total from dues		$6 651.59
From rents		1 000.00
From advertisements		973.00
From sale of JOURNALS		33.55
From contribution to building fund		100.00
Total		$9 073.14

We have examined the above report and found it correct.

ROBERT SPURR WESTON,
JOHN N. FERGUSON,
Directors.

REPORT OF THE EXCURSION COMMITTEE.

BOSTON, March 18, 1914.

The Excursion Committee had deemed it inadvisable during the past year to conduct any excursions except that in connection with the June meeting, when arrangements were made for a visit of inspection to the grade-crossing elimination work at Lynn, Mass. There were 18 members in attendance on this occasion.

For the Committee,
CHAS. R. GOW, *Chairman.*

ANNUAL REPORT OF LIBRARY COMMITTEE, 1913–1914.

BOSTON, MASS., March 18, 1914.

To the Boston Society of Civil Engineers:

The Library Committee submits herewith its annual report for the year ending March 18, 1914.

During the year 236 volumes bound in cloth and 679 bound in paper have been added to the library, not including some 35 volumes bound in paper which have been received and are now in the hands of the binder.

These additions have brought the number of cloth-bound volumes in the library up to 7 500, and have kept the number of volumes bound in paper still in the vicinity of 2 000, in spite of the large amount of binding that has been done.

Fines to the amount of $8.01 have been collected, and the committee is pleased to note that 309 books have been loaned to members, as against 204 loaned during the previous year, an increase of about 50 per cent.

Early in the year a few of the current engineering books were purchased, and a complete set of the Proceedings of the National Association of Cement Users, now the American Concrete Institute, has been bought recently. Most of the bound volumes added to the library, however, have consisted of

magazines, reports, and proceedings and transactions of Societies, which have been received in pamphlet form and bound at the Society's expense. Binding has seemed to be the only satisfactory way of preserving material that comes to us in this perishable form. A large mass of valuable material bound in paper was fast falling to decay, and it has seemed wise to your committee to preserve property of value already in the Society's possession, even if less actually new material were acquired. Among the volumes bound during the year may be mentioned ten volumes of the Proceedings of the Brooklyn Engineers' Club, seven volumes of the reports of the Isthmian Canal Commission, and a large number of volumes of the Minutes of the Proceedings of the Institution of Civil Engineers.

Much work has been done in the line of filling up gaps that existed in files of periodicals and society publications, and the committee has been greatly encouraged by the readiness of the members of the Society to contribute toward this work. Much indexing has also been done, though much remains to be done along both these lines.

Mr. Clemens Herschel has contributed a considerable number of volumes both to the general library and to the Herschel special library, and two new sections have been added to the cases containing the latter.

At the suggestion of several members, a section of advertising publications has been started, or rather, a former section of this nature which had not been kept up for some years has been revived. The firms applied to for material for this section have been very generous, and the committee feels that an excellent foundation has been laid for a collection of publications of this sort.

The exchange list of the JOURNAL is responsible for quite an increase in the number of periodicals received. In the matter of exchanges the JOURNAL has not confined itself to technical publications. The *Literary Digest*, *Harper's Weekly*, the *Outlook*, the *Atlantic Monthly* and *Harper's Magazine* are now on file at the rooms, and are apparently greatly enjoyed by the members. To the technical periodicals received regularly last year the exchange list has added the *American City*, *Canadian Engineer*, *Cement Era*, *Concrete-Cement Age*, *Journal of the Franklin Institute*, *Industrial Engineering*, *Machinery*, and the *Transactions* of the American Society for Testing Materials, the Connecticut Society of Engineers and the Engineers' Club of Philadelphia. The list of periodicals to which it is still necessary to subscribe is comparatively small.

To accommodate the above-mentioned increase in the number of magazines received, a new cabinet of some kind is needed, and the committee recommends that one be purchased.

The committee also recommends that the sum of sixty dollars be appropriated for the purchase of current engineering books during the coming year.

S. E. TINKHAM,
C. M. SPOFFORD,
FREDERIC I. WINSLOW,
Committee on Library.

REPORT OF THE EXECUTIVE COMMITTEE OF THE SANITARY SECTION.

BOSTON, MASS., March 4, 1914.

The Sanitary Section can now look back on ten years of active work, the first annual meeting having been held March 2, 1904, at the United States Hotel, Boston.

During the past year two excursions have been held. One in June, an excursion around Boston Harbor to the three principal sewage outlet works, and the other in October, to the Calf Pasture Pumping Station of the Boston Main Drainage Works.

Meetings have been held in March, December, January and February at the Engineers' Club, at which the following papers were presented:

March 5, 1913. — "A Glimpse of Tibet," Shaoching H. Chuan, M.D.

December 3, 1913. — "The Main Drainage Works Proposed for New York," Dr. George A. Soper.

January 7, 1914. — "The Arrowrock Dam of the United States Reclamation Service," Charles H. Paul.

February 4, 1914. — Discussion. Subject, "The Measurement of Sewage Flow."

"Sewage Measurement and Automatic Storm Overflow Control at Pawtucket, R. I.," George A. Carpenter.

"The Venturi Meter for Measuring Sewage," C. G. Richardson, of the Builders Iron Foundry.

Written discussions by Messrs. Edward Wright, Jr., Frank A. Marston, Frank B. Sanborn, Edwin H. Rogers and E. J. Fort, chief engineer of the Bureau of Sewers, Brooklyn, N. Y.

The paper presented at the December meeting has already been published in the JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS, February, 1914.

The papers presented at the February meeting will be published shortly, and it is hoped to publish the January paper, the final report of the Committee on Run-Off, and the report of the Committee on Sewerage Statistics, as well as the paper to be presented at this annual meeting, so that the Section will be well represented in the first volume of the Society JOURNAL.

The attendance has been as follows:

	Attendance at Dinner.	Attendance at Meeting.
March annual meeting	48	68
June excursion	72	77
October excursion	..	25
December meeting	34	75
January special meeting	30*	125
February special meeting	35	60
Average attendance not including excursions	..	82

This average is an increase of 32 over that of last year and is the highest average attendance at our meetings for any season since the organization of the Sanitary Section.

* Dinner arranged impromptu.

There have been 9 members added since the last annual meeting, making the present total membership of the Section, 159, of which 14 are members of the Sanitary Section only and 2 are Juniors, all of the remainder being members of the Society.

As we look back over the ten years' record of the Sanitary Section, it is evident that a considerable amount of valuable information has been placed on record through the papers presented. The attendance at the meetings has been sufficient to demonstrate the high degree of interest aroused. We should not stop at this point, however, with a self-satisfied feeling, but should look further toward the possibilities to be reached. What has the Section accomplished in the way of research work? At the first annual meeting of the Section the Committee on "Uniform Statistics of Sewer Construction and Maintenance" was appointed, showing that the intention from the beginning has been to take an active part in the extension of knowledge along sanitary lines. In the fifth annual report of the Executive Committee, presented March 4, 1908, the following will be found:

"In order to make the work of this Section valuable and keep up the interest, something should be done each year in the way of original research, for which the time and money should be provided. The committee hopes to see a fund made available for such work, by which these matters can be given the personal attention of some one, a member of the Section, who can be paid for his services."

In 1907 the Committee on Run-Off from Sewered Areas was appointed.

In 1908 a Committee on Collection and Tabulation of Sewerage Statistics was appointed to follow up the excellent work done by a former committee. The tabulations of statistics published by this committee have furnished valuable data to the profession. In this same year a committee was appointed to consider the subject of "Uniform Specifications for the Manufacture of Vitrified Sewer Pipe." This latter committee is still in existence, but owing to the desire to coöperate with a similar committee of the American Society for Testing Materials, it has been impossible to accomplish anything substantial in the way of progress.

Is it not time that additional work of this kind should be undertaken? There are many subjects of special interest which might properly be delegated to committee work, as, for example, —

Methods of assessing the cost of sewers on abutting property owners.

Collection of data regarding the cost and methods of construction and experience in operation of submerged pipe lines for outfall sewers.

Collection of data on sanitation of factory and mill buildings and matters affecting industrial occupations.

Your committee is of the opinion that the Section should carefully consider the general question of research work by committees, and if feasible, undertake additional work along this line.

Respectfully submitted.

For the Executive Committee,

FRANK A. MARSTON, *Clerk.*

BINDING THE JOURNALS.

MEMBERS who wish the Secretary to attend to the binding of their numbers of the *Journal of the Association of Engineering Societies* are requested to send them to Room 715, Tremont Temple, Boston, before April 15.

Arrangements have been made by which members can have the two volumes bound in one for 70 cents, or each volume bound separately for 50 cents; the style of binding to be the same and uniform with that of former years. Mark clearly which way it is desired the binding should be done.

As this will probably be the last opportunity members will have to secure the binding of their Journals under the present arrangement, they are urged to send in all numbers of back volumes which they intend to have bound.

APPLICATIONS FOR MEMBERSHIP.

[April 6, 1914.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

CHAPMAN, BENJAMIN RUSSELL, Brockton, Mass. (Age 49, b. East Dennis, Mass.) Attended Brockton High School. 1883 to 1891, with Elbridge L. Brown, civil engineer and surveyor, who till 1888 was acting as town and city engineer (during this time first investigations were made for establishment of sewerage system); 1891 to 1898, with F. Herbert Snow, city engineer, during greater part of this period as assistant engineer in charge of designing and carrying out to its completion the abolition of grade crossings within city limits; 1898, city engineer of Brockton; 1898 to 1913, principal assistant to city engineer of Brockton, now city engineer of Brockton. Refers to F. A. Barbour, C. R. Felton, W. S. Johnson, J. W. Rollins, R. S. Weston, G. H. Wetherbee, Jr., and H. L. White.

DRISCOLL, JAMES MICHAEL, Brookline, Mass. (Age 39, b. Brookline, Mass.) Graduate of Massachusetts Institute of Technology, 1896, civil engineering course, degree of S.B.; 1896 to 1900, rodman and instrumentman with Metropolitan Water Board; 1900 to 1901, with U. S. N. as structural steel draftsman, at Portsmouth, N. H.; 1901 to 1902, hydrographic draftsman on board U. S. S. *Vixen;* 1902 to 1903, Survey Colorado Reefs, Cuba; 1903, private surveying and road work; 1904, structural draftsman, Charleston, S. C.; 1904 to date, superintendent and engineer, Holyhood Cemetery Association. Refers to H. F. Bryant, G. E. Harkness, G. E. Russell, H. A. Varney.

HAGGETT, HAROLD DANIEL, Allston, Mass. (Age 28, b. Bath, Me.) Graduate of University of Maine, 1909. August, 1909, to January, 1910, with Pennsylvania Railroad; January to June, 1910, with Boston Elevated Railroad; June, 1910, to date, with Boston & Maine Railroad; is now transitman in engineering department. Refers to B. W. Guppy, T. P. Perkins, J. J. Rourke and F. B. Rowell.

HAYWARD, EDWIN DANIEL, Bridgewater, Mass. (Age 22, b. Bridgewater, Mass.) From 1910 to date, student at Massachusetts Institute of Technology, civil engineering course. Refers to C. F. Allen, A. E. Burton, A. G. Robbins and C. M. Spofford.

LAWRENCE, BEARSDLEY, Dorchester, Mass. (Age 26, b. Short Hills, N. J.) Student at Massachusetts Institute of Technology, civil engineering course, 1907 to 1909 (one and one-half years). June to October, 1909, rodman with Charles River Basin Commission; October, 1909, to May, 1912, rodman and instrumentman with Metropolitan Water and Sewerage Board; May to December, 1912, engineer with San Domingo Light and Power Company, Santiago, San Domingo; December, 1912, to date, instrumentman with Metropolitan Water and Sewerage Board. Elected a junior, October 16, 1912, and now desires to be transferred to grade of member. Refers to J. N. Ferguson, C. F. Fitz, Jr., Clifford Foss, W. E. Foss and B. A. Rich.

MANN, OSWELL F., Somerville, Mass. (Age 33, b. Brockton, Mass.) Graduate of English High School, 1897. With E. G. Mann one and one-half years; 1899 to 1903, with E. Harrington & Co.; December, 1903, to May, 1904, on appraisal work with Gilbert Hodges; 1904 to date, with Edison Electric Illuminating Company of Boston; is at present head of Conduit

Division, Street Engineering Department. Refers to R. E. Curtis, G. D. Emerson, F. A. Snow and S. E. Tinkham.

Morrow, Clarence Edgar, Boston, Mass. (Age 25, b. Columbus, Ohio.) Graduate of Whitman College in 1910 and of Massachusetts Institute of Technology, architectural engineering course, in 1912. June to September, 1909, 1910 and 1912, with Gilbert Hunt Company, Walla Walla, Wash., first summer as machinist, second as assistant foreman in fabrication shop, third as draftsman; June to September, 1913, engineer, with W. W. Bosworth, architect, New York City; September, 1912, to date, instructor in Architectural Engineering at Massachusetts Institute of Technology; November to December, 1913, with Prof. C. M. Spofford on design of Chelsea Bridge, South; January, 1914, to date, with Stone & Webster (Cambridge office), mornings, as structural engineer. Refers to W. W. Clifford, W. H. Lawrence, E. F. Rockwood and C. M. Spofford.

Nichols, Charles Eliot, Watertown, Mass. (Age 29, b. Somerville, Mass.) Received degree of A.B. from Harvard College, 1907; student for two years in structural engineering at Harvard Graduate School of Applied Science. 1910 and 1911, draftsman and designer in Seattle, Wash., and Portland, Ore., with Stone & Webster Engineering Corporation, and with Doyle, Patterson & Beach, architects; February, 1912, to date, with Stone & Webster Engineering Corporation on following work: to October, 1912, designer on station of Mississippi River Power Company at Keokuk, Ia.; October, 1912, to April, 1913, inspector and field engineer at power house of Boston Woven Hose & Rubber Co.; April to October, 1913, in charge of drafting and designing of concrete construction in Boston office; October, 1913, to date, structural engineer in charge of design of new Massachusetts Institute of Technology buildings at Cambridge. Refers to H. K. Alden, W. W. Clifford, L. J. Johnson, Mark Linenthal, W. N. Patten, E. F. Rockwood and S. E. Thompson.

Sabin, Fred Dexter, Somerville, Mass. (Age 28, b. Meadville, Pa.) Professional education obtained at Lawrence Scientific School and Harvard University. 1902 to 1904, rodman and transitman with engineering department, city of Cambridge; 1904 to 1906, at college; 1906 to 1907, transitman with engineering department, city of Cambridge; dredging inspector with Massachusetts Harbor and Land Commission (two months); 1907 to date, resident engineer with Massachusetts Highway Commission. Refers to G. F. Hooker, A. M. Lovis, A. E. Tarbell and R. A. Vesper.

Sherman, Herbert L., Belmont, Mass. (Age 32, b. Kingston, Mass.) Graduate of Massachusetts Institute of Technology, 1902, in chemistry. From graduation till 1904, assistant in mineralogy at Massachusetts Institute of Technology, chemist with Massachusetts State Board of Health, chemist with Helderberg Cement Company, and cement tester with United Shoe Machinery Co.; 1904 to 1914, has conducted business of industrial and engineering chemist, specializing in cement and concrete, in Boston; has just been instrumental in forming New England Bureau of Tests, of which he is

president, engaged in general inspection, testing and analysis of all commercial products, with branch laboratories in all the mill districts. Refers to J. N. Ferguson, F. W. Hodgdon, C. T. Main, C. W. Sherman, E. C. Sherman and J. R. Worcester.

WARING, CHARLES THOMAS, Sandwich, Mass. (Age 37, b. Philipsburg, Pa.) Graduate of Philipsburg High School; 1893 to 1896, engaged in private study with A. V. Hoyt, civil engineer. With Isthmian Canal Commission, first as rodman to assistant engineer in charge of Residency Division of Municipal Engineering, April, 1905, to November, 1908; then as assistant engineer in charge of general surveys, Third Division of Office of Chief Engineer, 1908 to 1909; with Cape Cod Construction Company, as division engineer, November, 1909, to March, 1912; as resident engineer, March, 1912, to date. Refers to H. S. Adams, H. W. Durham, F. W. Hodgdon, J. W. Rollins, C. M. Saville and W. F. Williams.

EMPLOYMENT BUREAU.

THE Board of Government has established an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

MEN AVAILABLE.

221. Age 21. Graduate of Mechanics Arts High School, 1911; now third-year student in civil engineering course at Massachusetts Institute of Technology. Has had one summer's experience doing field work in plane, topographical and hydrographic surveying, as well as railroad field work at M. I. T. summer surveying camp; has had considerable experience as a chauffeur. Desires position as instrumentman for the summer.

222. Age 26. Graduate of Massachusetts Institute of Technology, 1911, in electrical engineering course. Has had five seasons' experience as theater electrician; was with General Electric Company Lamp Works, Harrison, N. J., for eight months; has been two years with Standard Plunger Elevator Company, Worcester, Mass., as chief estimating engineer. Desires position in any line of engineering work for which this experience qualifies him.

223. Age 43. Had four years' special course in civil engineering at Massachusetts Institute of Technology. Has had fifteen years' experience on land and topographical surveys, location, design and construction of roads,

and plain and reinforced concrete walls and bridges; five years' experience in charge of heavy excavation and aqueduct construction. Desires position in charge of concrete construction or road building. Salary desired, $150 per month.

224. Age 42. Graduate of Massachusetts Institute of Technology in electrical engineering, class of 1894. Has had seventeen years' experience in charge of electric lighting plant of Lonsdale Company, cotton manufacturers, Lonsdale, R. I.; January, 1913, engaged by Boston & Providence Railroad Corporation, as assistant engineer, representing their interests in proposed four-tracking and electrification of their road by New Haven Railroad, which work has been indefinitely postponed. Desires position along electrical and mechanical lines, either construction or operation. Salary dependent upon position and future prospects.

225. Age 18. High school graduate and student for one half-year at Massachusetts Institute of Technology. Has had one summer's experience as rodman on topographic work, with H. F. Bryant, Brookline, Mass. Is willing to accept any position that will give him experience along engineering lines.

226. Age 19. Student at Phillips-Exeter Academy for two years and at Dartmouth College two and one-half years; at present student at Massachusetts Institute of Technology. Has worked for several summers with different engineers, but mostly with H. M. McIntosh, civil engineer, Burlington, Vt. Desires position as rodman or transitman. Salary desired, $12 to $15 per week.

227. Age 37. Has had ten years' experience on various state commissions and on municipal work; for past five years has been assistant engineer, principally on design and construction of sewerage systems. Salary desired, $125 per month.

Position Available

Rodman wanted on state highway work. Man having knowledge of use of transit and principles of drafting preferred. Salary $60 per month and expenses in field.

LIST OF MEMBERS.

ADDITIONS.

Bildt, A. Fredrik.................... 1182 Harrison Ave., Roxbury, Mass.
Gartland, Edward Vincent.............. 20 Roslin St., Dorchester, Mass.

CHANGES OF ADDRESS.

Burden, Harry P. . . . . 60 Lewis St., East Lynn, Mass.
Clapp, Wilfred A. . . . . 68 Ramona Ave., Oakland, Cal.
Coburn, Howard L. . . . . 61 Broadway, New York, N. Y.
Dutton, Charles H., care J. R. Worcester & Co., 79 Milk St., Boston, Mass.
Eglee, Charles H. . . . . 8 Beacon St., Boston, Mass.
Emerson, Ralph W. . . . . 20 Boylston St., Pittsfield, Mass.
Fox, Samuel, Jr. . . . . 93 Newbury St., Boston, Mass.
Hall, Harry R. . . . . 16 West Saratoga St., Baltimore, Md.
Howe, Edward W. . . . . 26 Wayne St., Roxbury, Mass.
Johnson, Frank W., care Ambursen Co. . . . . 61 Broadway, New York, N. Y.
Kidd, Alexander L. . . . . 43 Sagamore St., Dorchester, Mass.
Kimball, Ernest R. . . . . 40 Upland Road, Arlington, Mass.
Tibbetts, Fred E. . . . . 125 Liberty Road, W. Somerville, Mass.

Resignations.

(In effect March 18, 1914.)

Baldwin, Thomas A.
Bigelow, James F.
Chisholm, Ivan A. F.
Church, William L.
French, Edmund M.
Hansen, Paul
Howe, George E.
Hyde, Charles G.
Pitman, Lawrence M.
Phelps, Earle B.
Ransom, Horace U.
Richards, Walter H.
Robinson, Walter F.
Trefethen, Ernest M.
Watson, William
Wetherbee, George A.
White, George V.
Whitney, George E.

LIBRARY NOTES.

Recent Additions to the Library.

U. S. Government Reports.

Annual Reports of Chief of Engineers of War Department, Vols. 4, 5 and 6 for 1897, and Vol. 1 for 1898. Gift of E. H. Rogers.

Forest Tree Diseases Common in California and Nevada. E. P. Meinecke.

Fuel-Briquetting Investigations, 1904–12. C. L. Wright.

State Reports.

Maine. Annual Reports of Railroad Commissioners for 1906, 1908, and 1910–13 inclusive.

Ohio. Wood-Using Industries, 1912. Carroll W. Dunning.

County Reports.

Essex County, Mass. Annual Report of County Engineer for 1913.

City and Town Reports.

Cambridge, Mass. Annual Report of City Engineer for 1912–13.

New York, N. Y. Preliminary Reports on Sewage Disposal, XI–XIV inclusive.

Northampton, Mass. Annual Report of Water Commissioners for 1913.

Peabody, Mass. Annual Report of Commission of Public Works for 1913.

Providence, R. I. Annual Report of City Engineer for 1912.

Providence, R. I. Annual Report of Department of Public Works for 1913.

Reading, Mass. Annual Report of Water Commissioners for 1913.

Rutland, Vt. Annual Report of City Officers for 1913.

Wellesley, Mass. Annual Report of Water and Light Commissioners for 1913.

Miscellaneous.

Bridges of Cleveland. Henry Grattan Tyrrell.

Canada, Dept. of Mines. Annual Report on Mineral Production of Canada for 1912. Preliminary Report on Mineral Production of Canada for 1913.

Esthetic Treatment of City Bridges. Henry Grattan Tyrrell.

Naval Architects and Marine Engineers: Transactions for 1909.

Recall of Constitutional Safeguards. Rome G. Brown.

Trussed Concrete Steel Co. Hy-Rib Concrete Silos and Farm Buildings, 5th ed.

We have been unable to procure from headquarters a copy of the Annual Report of the Railroad Commissioners of the State of Maine for 1909, which is the only volume now needed to make our file complete. Can any one of our members supply us with a copy?

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before the 25th of each month.)

United States Government. — NAVY DEPARTMENT. — *Navy Yard, Boston.* — Work is now in progress or new work is contemplated as follows:

WORK IN PROGRESS.

Mold loft floor for new supply ship.

Timber wharf extension at Naval Magazine, Hingham.

Reconstruction of Building No. 24: reinforced concrete.

Remodeling Building No. 77 for use as boat storage, including equipment with crane service.

Two 300-ft. radio towers on Naval Hospital Reservation, Chelsea. (Contract let.)

Building for central heating plant, Naval Hospital, Chelsea, to be built by day labor.

NEW WORK CONTEMPLATED.

Fireproof floor, sprinkler system and metal storage racks, pattern shop, Building No. 42.

Building ways for construction of new supply ship.

Commonwealth of Massachusetts. — METROPOLITAN PARK COMMISSION. — *Woburn Parkway.* — Work of construction of Woburn Parkway is in progress.

Charles River Reservation, Lower Basin. — Work of construction of retaining wall along Broad Canal on property of Horgan Estate is in progress.

Directors of the Port of Boston. — *Dry Dock.* — Office force working on plans and H. P. Converse & Co. constructing bulkhead.

Viaduct. — Steel work completed.

Railroad Yard. — Contractor shipping material for the work.

Heating Plant. — Nearly completed.

Commonwealth Pier No. 5. — Contractor at work on Headhouse.

Commonwealth Pier No. 1. — Office force at work on plans. Old pier being removed. Dredging partly done.

Massachusetts Highway Commission. — A three-span reinforced concrete arch bridge is under construction at Onset between Onset and Point Independence in Wareham. One abutment and three piers are completed. Work now being done on second abutment and one arch. Forms are practically completed for arch, and concrete will be placed during week of March 30, weather permitting.

Revere Traffic Road, extending from Point of Pines southerly to Revere St., including bridge over Boston, Revere Beach & Lynn R. R., and Boston & Maine R. R., is now under construction. Steel bridge with concrete floor is to be placed during month of May. The road surface is to consist of broken stone, bound with tar by the penetration method.

A reinforced concrete arch bridge is being constructed in Blackstone in connection with a bituminous macadam road surface about one and one-half miles in length.

Metropolitan Water and Sewerage Board. — *Sewerage Works.* — Work on Sections 69 and 70, new Mystic Sewer, at Winchester, is in progress.

Boston Transit Commission. — *Boylston Street Subway and Dorchester Tunnel.* — No change since last report as printed in the March Journal.

East Boston Tunnel Extension. — Section G. — No change since last reports except that the work of underpinning the

buildings east of Cornhill has begun. Isaac Blair & Company, Inc., is the contractor.

Section H is located in and near Court and Cambridge Sts., extends from Stoddard St. to Staniford St., and includes the Bowdoin Square station. The structure is to be mainly of reinforced concrete with steel columns and roof beams for a portion of the way. The contract has been awarded to Coleman Bros., and the work has been started.

Section J extends from Staniford St. to North Russell St. The incline in Cambridge St. between Chambers St. and North Russell St. has been built. Excavation is proceeding between Staniford and Chambers streets. The walls of the tunnel are partly built and a considerable portion of the roof has been placed in this vicinity. Coleman Bros. are the contractors.

City of Boston. — PUBLIC WORKS DEPARTMENT, SEWER AND WATER DIVISION. — *Sewer Service.* — The following work is in progress:

Mattapan Brook between Norfolk and Delhi Sts., Mattapan. 5 ft. 6 in. concrete conduit; 15-in. pipe supplementary sewer. Rock cut. Haines-Weaver mixer at work on this job.

Spring St. Brook between Summer and Centre Sts., West Roxbury. American Vitrified Segment Sewer block being used on this job; 5 ft. 3 in.

Albany St. at Union Park St., South End. Double concrete conduit being built on piles. Size, 4 ft. 10 in. x 10 ft. 6 in., together with 2 ft. 9 in. x 10 ft. 6 in.

Aberthaw Construction Company. — At South Boston, at the end of the Fish Pier, the Aberthaw Construction Company is putting up the steel frame and concrete buildings for the Commonwealth Ice and Cold Storage Company. The power house and machinery building have been completed. The foundations are complete on the main cold storage building and the ice wing is framed in and the concrete work started. The most interesting features of the job are the contractor's methods of handling work on a task and bonus basis. This they would be glad to show any member of the Society that cares to visit the

work. The method of handling fairly high concrete buildings during winter weather is worth examination.

The Fore River Shipbuilding Co., Quincy, Mass., has the following new work in progress:

U. S. Battleship *Nevada*.

U. S. Submarine Tender *Fulton*.

Nine U. S. submarine boats.

U. S. Torpedo Boat Destroyers *Cushing* and *No. 57*.

Vol. I MAY, 1914 No. 5

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

PROCEEDINGS

PAPERS IN THIS NUMBER.

Report of Committee on Sewerage Statistics.

"The Collection and Treatment of Sewage in Their Relation to the City of Philadelphia." George S. Webster.

(Presented before the Sanitary Section, March 4, 1914.)

CURRENT DISCUSSIONS.

Paper.	Author.	Published.	Discussion Closes.
"Boston Foundations."	J. R. Worcester.	Jan.	May 10.
"Engineering Lessons from the Ohio Floods."	John W. Alford.	March.	May 15.
"Bitulithic Pavement and Warrenite Roadway."	G. H. Perkins.	March.	May 15.
"Cost Accounting on Construction Work."	Leslie H. Allen.	March.	May 15.

NOTE. At the request of a number of members of the Society the date of closing the discussion of "Boston Foundations" has been extended to May 10.

REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on Wednesday, May 20, 1914, at 7.45 o'clock P.M., in

CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Business of the Meeting.— To act on the vote passed at the last meeting, authorizing the Board of Government to use an appropriation from the Permanent Fund equivalent to the amount of the entrance fees for the fiscal year of 1913 and for the fiscal year of 1914. Under the By-Laws it requires an affirmative vote of two thirds at two successive regular meetings, to make an appropriation from the Permanent Fund.

Mr. Edward S. Larned will give a talk on "The Manufacture of Portland Cement," illustrated with motion pictures.

S. E. Tinkham, *Secretary*.

JUNE EXCURSION OF SANITARY SECTION.

The annual June excursion of the Sanitary Section will be held Wednesday, June 3, 1914, at Fitchburg, Mass. The excursion will include an inspection of the new sewage treatment works, consisting of Imhoff tanks, sludge beds, sprinkling filters, secondary settling tanks, laboratory building, Venturi meter, and other features of interest.

Pamphlets will be provided giving the principal facts and detailed drawings of the plant.

All members of the Society and guests are invited.

A special notice will be mailed to members giving more detailed information in regard to the trip.

MINUTES OF MEETINGS.

Boston, March 25, 1914. — A special meeting of the Boston Society of Civil Engineers was held this evening at the Society Rooms, 715 Tremont Temple, and was called to order at 8 o'clock by the President, Mr. Harrison P. Eddy. In the absence of the Secretary, Mr. James E. Stone was elected Secretary *pro tem.* There were 52 members and guests present.

Mr. Leslie H. Allen read the paper of the evening, entitled "Cost Accounting on Construction Work."

The remainder of the meeting was devoted to a discussion of Mr. Allen's paper. Written discussions by Mr. Dana M. Wood, member of the Society, and by Mr. M. L. Cooley, of Cooley & Marvin Company of Boston, were presented and read. The paper was further discussed by Dr. Seldon O. Martin, of Harvard University; Mr. C. Oliver Wellington, of Clinton H. Scovell Co.; Mr. Merton W. Hopkins, of the New England Concrete Construction Co.; and by Mr. Burtis S. Brown, Mr. Bertram Brewer, President Eddy and Mr. Allen of the Society.

At 9.45 o'clock the meeting adjourned.

James E. Stone, *Secretary pro tem.*

Boston, April 15, 1914. — A regular meeting of the Boston Society of Civil Engineers was held this evening at 7.50 o'clock, in Chipman Hall, Tremont Temple, President Harrison P. Eddy in the chair. There were 115 members and visitors present.

In the absence of the Secretary, on motion of Mr. Wason, Mr. J. E. Carty was elected Secretary *pro tem.*

The reading of the records of the annual meeting and of the special meeting of March 25, 1914, was by vote dispensed with, and the record of the annual meeting approved as printed in the April number of the Journal.

The Secretary *pro tem.* announced the election by the Board of Government of the following new members in the grades named:

Members — Arthur Lassell Shaw and Clarence McLellan Weston.

Juniors — George Robert Burnes, Lyle Merton Richardson and Stanley Ward Woodbury.

Announcement was made of the following committees appointed by the Board of Government:

On Excursions — Leonard C. Wason, Bertram Brewer, Leonard L. Street, George A. Sampson.

On the Library — S. Everett Tinkham, Henry F. Bryant, Frederic I. Winslow.

On Publication — Joseph R. Worcester, Richard K. Hale, Arthur T. Safford.

On Membership — F. H. Fay, chairman; H. S. Adams, G. A. Carpenter, J. E. Carty, H. N. Cheney, L. S. Cowles, R. E. Curtis, A. W. Dean, C. R. Gow, F. M. Gunby, E. S. Larned, L. B. Manley, I. E. Moultrop, J. F. Osborn, E. E. Pettee, E. H. Rockwell, W. H. Sawyer, C. M. Spofford, L. L. Street, David Sutton.

The death of Albert H. Howland, a member of the Society, which occurred on April 5, 1914, was announced by the President, and on motion of Mr. Fay the President was requested to appoint a committee to prepare a memoir. He has appointed as this committee Messrs. Frederick Brooks and Frank L. Fuller.

Mr. Fay offered an amendment, as printed in the notice of the meeting, to By-Law 9, so that, if said amendment were adopted, the By-Law would read: Permanent Fund. — There shall be a fund called the Permanent Fund, to which shall be added all money received for entrance fees and all income from investments of the fund, *provided, however, that the income of the the fund, or any portion thereof, in any year may be used for current expenses of that year, at the discretion of the Board of Government.* No money, *other than income above specified*, shall be appropriated from the fund except by a two-thirds vote at two successive regular meetings. Any such appropriation or any part thereof not used within three years shall be returned to the fund.

An animated discussion took place, which lasted until the President, in accordance with the By-Laws, postponed the discussion until after the literary exercises. After the conclusion of the literary exercises, the subject was opened again for discussion. A rising vote was then taken on the adoption of the amendment, 17 voting in favor and 14 against. The President thereupon declared the amendment lost.

Prof. C. Frank Allen moved that the Board of Government be authorized to use an appropriation from the Permanent Fund equivalent to the amount of the entrance fees for the fiscal year of 1913 and for the fiscal year of 1914. The motion

was seconded by Professor Sanborn. After a thorough discussion, a rising vote was taken, 25 voting in favor of the motion and 5 against. The President declared the motion carried and stated that it would come up for action again at the next meeting of the Society.

At the beginning of the literary exercises, the President welcomed the members of the Massachusetts Highway Association, and then introduced as the speaker of the evening, Mr. J. S. Miller, Jr., assistant chief chemist of the Barber Asphalt Paving Company, who gave an interesting lecture, illustrated with motion pictures, entitled "Asphalt and Asphaltic Street and Road Construction." A number of questions were asked the speaker, showing the interest taken in the lecture.

The meeting was adjourned at 10.30 o'clock.

JOHN E. CARTY, *Secretary pro tem.*

APPLICATIONS FOR MEMBERSHIP.

[May 1, 1914.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

Ackerman, Alexander Seymour, Sandwich, Mass. (Age 34, b. Newburyport, Mass.) Student at Mass. Inst. of Technology for two and one-half years, Class of 1903. From June to September, 1901, sewer inspector, Newburyport; October, 1901, with J. P. Titcomb on surveys; November, 1901, to July, 1904, cartographer, Naval War College, Newport, R. I.; April and May, 1905, draftsman with C. H. Davis, So. Yarmouth; June, 1905, with Engrg. Corps as inspector of breakwater repairs; July to October, 1905, rodman and instrumentman with Engrg. Corps, Penn. Lines west of Pittsburgh; October, 1905, to September, 1907, with Division of Municipal Engrg., I. C. C., as rodman, levelman and transitman, on sewers, roads and water works; September, 1907, to date, with Cape Cod Construction Co. as asst. engineer, division engineer and senior asst. engineer. Refers to H. W. Durham, F. W. Hodgdon, A. J. Ober, J. W. Rollins and W. F. Williams.

Burpee, George William, New York, N. Y. (Age 30, b. Sheffield, New Brunswick.) Graduate of Bowdoin College, degree of A.B., 1904; graduate of Mass. Inst. of Technology, degree of S.B., 1906. During summer vacations, 1900 to 1903 inclusive, with Bangor & Aroostook R. R. in various subordinate positions on engineering staff; from June to September inclusive, 1905, chainman and rodman with maintenance of way department, Atchison, Topeka & Santa Fé R. R.; from June, 1906, to January, 1907, in office of chief engineer, Louisville & Nashville R. R.; from February, 1907, to June, 1911, with Westinghouse, Church, Kerr & Co., as field engineer on construction of power house and transmission line for Edison Electric Light Co., Brockton, Mass.; on valuation of electric properties for N. Y., N. H. & H. R. R.; assistant superintendent of construction on power house for Worcester, Mass., Electric Light Co.; also miscellaneous field and office work; from July to December, 1911, resident engineer, Canadian Northern Ontario Ry.; from January, 1912, to date, with Westinghouse, Church, Kerr & Co., chiefly engaged in investigations of engineering projects, more especially those relating to railways. Refers to C. F. Allen, E. J. Beugler, R. D. Bradbury, Moses Burpee, J. H. O'Brien, G. F. Swain and L. W. Tucker.

Ellis, Lester Fisher, Winter Hill, Mass. (Age 28, b. Woonsocket, R. I.) Graduate of Tufts College Engineering School, 1909. From 1909 to date, period of four and three-quarters years, with J. R. Worcester & Co. Refers to J. W. Ellis, C. R. Gow, E. A. Norwood, E. E. Pettee, H. B. Pratt, and Gilbert Small.

Enebuske, Carl Claësson, Cambridge, Mass. (Age 25, b. New York, N. Y.) Educated in private schools in Newton, and in Paris, France; 1904 to 1908, student in scientific course at Lycée Janson-de-Sailly, Paris, France. From October, 1908, to date, draftsman with J. R. Worcester & Co. Elected a Junior, March 20, 1912, and now desires to be transferred to grade of Member. Refers to G. H. Brazer, C. H. Dutton, E. E. Pettee and J. R. Worcester.

French, Charles Augustus, Laconia, N. H. (Age 42, b. Springfield,

Mass.) Graduate of Dartmouth College, 1893, degree of B.S. In 1893, with Board of Survey, City of Boston; 1894, with Sewer Department, City of Malden; from 1895 to 1901, with Metropolitan Water Board; from 1901 to 1906, Superintendent of Streets and Sewers, Marlboro, Mass.; from 1906 to present time, City Engineer, Laconia, N. H. Refers to M. A. Brown, F. H. Fay, W. B. Howe, E. S. Larned, W. H. G. Mann and J. W. Storrs.

Gray, Howard Allison, Somerville, Mass. (Age 25, b. Somerville, Mass.) Educated in Somerville public schools and at Tufts College, from which institution he received degree of B.S. in Structural Engineering in June, 1911. With New England Structural Co. in template shop during summer months of college course; from June, 1911, to April, 1912, with same company in drawing office; April, 1912, to date, with Edison Electric Illuminating Co. of Boston, on drafting specifications, design of building construction and alterations, and checking of drawings. Refers to R. E. Curtis, I. E. Moultrop, T. E. Penard, E. H. Rockwell, F. B. Sanborn and J. P. Snow.

Mead, Royal Lee, Boston, Mass. (Age 30, b. Livingston, Mont.) Received high school education at Virginia City, Mont., and Northfield, Vt.; student for two years at Norwich University in Civil Engineering course. From April to September, 1910, rodman and instrumentman with C. A. Thayer, Providence, R. I.; September, 1910, to March, 1913, rodman and instrumentman with Boston Elevated Street Railway Co.; March, 1913, to April, 1914, draftsman in Engineering Department of Directors of Port of Boston; April, 1914, to date, steel designer and structural draftsman with Stone & Webster Engrg. Corp'n. Refers to J. F. Connell, H. R. Draper, C. T. Fernald and Daniel Scouler.

Milton, Samuel Lawrence, Roxbury, Mass. (Age 28, b. Boston, Mass.) Student at Harvard University, 1905–08, mining and civil engineering courses; at Colorado School of Mines, 1908–09 (first semester); one year, evenings, with private consulting engineer, in reinforced concrete design work; one half-year, 1912, at Lowell Institute, for industrial foreman in electrical engineering course. From January, 1909, to February, 1911, with B. & A. R. R. in following positions: Instrumentman on station surveys, etc., inspector on new passenger station at Worcester, Mass., inspector and draftsman on new bridges in western Massachusetts, steam power station at Springfield, Mass., third tracking and State line tunnel; from March to August, 1911, with E. L. Ransome on design and construction of United Shoe Machinery buildings at Beverly, Mass.; from August to December, 1911, with Lockwood-Greene Co., on mill buildings, industrial plants, etc.; from January, 1912, to date, with Stone & Webster Engrg. Corp'n in following positions: Structural steel and reinforced concrete draftsman, hydraulic designer, efficiency supervisor, and (September, 1913, to date) engineer in charge of tests on new Mass. Inst. of Technology buildings at Cambridge; summer of 1906 at Harvard engineering camp; summer of 1907, at mining camp, Leadville, Colo.; summer of 1908, at mining camp, Bisbee, Ariz. Refers to H. K. Alden, Mark Linenthal, C. T. Main, L. G. Morphy and F. J. Wood.

ROBINSON, ASHLEY QUINCY, Attleboro, Mass. (Age 20, b. Webster, Mass.) Graduate of grammar school, Ware, Mass.; studied with father, Charles F. Robinson, C.E., Attleboro, Mass. From 1908 to 1912, rodman and transitman with C. F. Robinson, Attleboro, Mass.; from 1912 to June, 1913, inspector on sewer construction with J. J. Van Valkenburgh, C.E.; from August, 1913, to date, inspector on sewer construction with Metcalf & Eddy, Boston. Refers to H. P. Eddy, J. A. McKenna, F. A. Marston, J. J. Van Valkenburgh and J. P. Wentworth.

STORRS, EDWARD DOW, Concord, N. H. (Age 28, b. Concord, N. H.) Student at Dartmouth College in 1904; studied designing under John W. Storrs during winter of 1907–08. From spring of 1905 to spring of 1907, with engineering department of B. & M. R. R., first as rodman on general surveying work, later as bridge inspector; with Empire Bridge Co., Elmira, N. Y., as draftsman on detailing of bridge work, during part of 1907; engineer in charge of Connecticut River bridge at Claremont, N. H., summer of 1908; designed steel bridge over Merrimac River at Hooksett, N. H., 1909; steel bridge over Pemigewasset River at Hill, N. H., 1913; and numerous shorter spans, including bridges for towns of Wentworth, Tilton, Shelburne and Pembroke, N. H.; now junior member of firm of Storrs & Storrs, Bridge Engrs., Concord, N. H. Refers to W. B. Howe, F. W. Lang, W. H. G. Mann, J. P. Snow, J. W. Storrs and L. J. Wertheim.

TAYLOR, GEORGE, Wollaston, Mass. (Age 38, b. Athens, Ont.) Graduate of Athens High School, 1893; taught school three years; graduated from Brockville Business College, 1897; taught in College one year. From 1898 to date, with Eastern Expanded Metal Co., during past nine years as General Manager; familiar with different kinds of construction, especially that of concrete, plain and reinforced. Refers to C. R. Gow, E. F. Rockwood, L. L. Street and W. O. Wellington.

WILLIAMS, ALEXANDER KILPATRICK, Boston, Mass. (Age 32, b. Boston, Mass.) Graduated from Mechanic Arts High School, and took two years' course in steel and concrete designing at Boston Y. M. C. A. In 1899 entered the employ of C. A. Dodge & Co., General Contractors; worked on construction of buildings for three years, entered the office as estimator, became stockholder and director in 1908; has entire charge of estimating and detailing of reinforced concrete work on all work under contract. Refers to Joseph Driscoll, C. R. Gow, L. G. Morphy, L. L. Street and W. O. Wellington.

EMPLOYMENT BUREAU.

THE Board of Government has established an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for

furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

Men Available.

193. Age 26. Graduate of Mass. Inst. of Technology, Civil Engineering Course, 1910, degree of B.S. Experience includes work as rodman with Charles River Basin Comm. and Boston Elevated Railway Co.; transitman on pipe line and concrete drain construction with Metropolitan Water & Sewerage Board; draftsman with Fore River Shipbuilding Co., on survey and map of entire plant; transitman and chief of party on electric and steam railroad location, construction and maintenance; was for more than a year principal assistant to resident engineer for Worcester Consolidated St. Ry. lines; from August to December, 1913, was esident engineer on construction of Portland, Gray & Lewiston R. R.; is now in private practice as civil engineer and surveyor. For position desired and minimum salary expected please interview at office.

199. Age 23. Graduate of New Britain, Conn., High School; student for one year at University of Maine. Has had two years' experience as rodman and transitman with engineering department of city of Newton, and three months' experience as general assistant with local engineer. Desires position as transitman or sewer inspector. Salary desired, $15 per week.

228. Age 45. Graduate of Mass. Inst. of Technology, degree of B.S. Experience includes five years on railroad construction; eight years as division engineer, principal assistant and chief engineer on sewer construction; fifteen months with National Board of Fire Underwriters on investigations and reports on fire protection of large cities of U. S.; five years in charge of surveys and construction, Reservoir Dept., City of New York; and more than two years on steel tower transmission line construction, Keokuk to St. Louis and in California. Will consider any reasonable position and salary for which experience qualifies him.

229. Age 28. Student for one year at Dartmouth College; has taken special courses in railroad and reinforced concrete engineering. Experience includes three years with Metropolitan Park Comm. of Boston as rodman, transitman and chief of party; five years on railway and general construction work in Cuba and Porto Rico; and two years with Porto Rico Construction Co. as resident engineer on construction of Ambursen dam at Comerio Falls. Desires position as engineer on construction. Salary desired, $125 per month.

230. Age 25. Has had equivalent of two years of university work. Has had five years of good practical experience on city, land, railway, and

hydro-surveys, and construction; also office work connected therewith. Desires position as instrumentman, recorder or inspector, with contractor or firm of engineers and constructors. Salary desired, $75 per month.

231. Age 26. Possesses liberal literary and commercial education. Has had nearly nine years of excellent clerical experience in Mechanical, Purchasing, Passenger, Legal and Engineering Departments of eastern and southern railways, including several months with B. & M. R. R., Boston; two years' work in connection with South Station Ticket Office, Boston; and five years with Florida East Coast Railway Co., on Key West Extension; still holds position with this Company as chief clerk of office, in charge of clerical force of five, work including supervision of all routine, preparation of various reports, statements, etc., employment and assignment of workmen, checking of payrolls, handling of considerable correspondence, and transcription of estimates and survey notes, as well as numerous other papers such as issue from an important engineering office; is conversant with ordering, checking and handling of railway, mechanical, subsistence and miscellaneous supplies. Desires clerical position in office of consulting or constructing engineer or contractor, in vicinity of Boston.

LIST OF MEMBERS.

ADDITIONS.

Langley, Miles E. .... 127 M St., South Boston, Mass.
Richardson, Lyle M. .... 237 Beacon St., Boston, Mass.
Shaw, Arthur L. .... 6 Beacon St., Room 809, Boston, Mass.
Weston, Clarence M. .... 200 Fifth Ave., Room 1303, New York, N. Y.
Wight, Willard W. .... Wellesley Hills, Mass.

CHANGES OF ADDRESS.

Barnes, T. Howard .... Room 1627, 17 Battery Pl., New York, N. Y.
Bigelow, William W. .... 624 State St., Springfield, Mass.
Bliss, Hermon R. .... 35 Boylston Ave., Providence, R. I.
Bradbury, Edward C. .... Commercial Bldg., Columbus, Ohio.
Brunel, Richard
Care of J. R. Worcester & Co., 550 Masonic Bldg., Portland, Me.
Cobb, William A. .... Wilson's Mills, Me.
Craib, Charles G. .... 2183 Hutchison St., Montreal, P. Q.
Draper, Harry R. .... Box 143, Ayer, Mass.
Durham, Henry W. .... Manhattan Municipal Bldg., New York, N. Y.
French, Herman W. .... Town Hall, Brookline, Mass.
Gould, Gardner S. .... 551 E. Summit St., Kent, Ohio.
Hartwell, David A. .... 745 Main St., Fitchburg, Mass.
Lavalle, Albert H. .... 274 Main St., Springfield, Mass.

LEE, EDWARD G. .... 83 Highland St., Woodfords Sta., Portland, Me
LINK, J. WILLIAM .... 206 S. La Salle St., Suite 1900, Chicago, Ill.
McKENZIE, WALTER S. .... 54 Upland Rd., Quincy, Mass.
MAIN, CHARLES R. .... P. O. Box 1004, Great Falls, Mont.
MALLEY, PATRICK J. .... 65 City Hall, Boston, Mass.
PARLIN, RAYMOND W.
Care of Bureau of Municipal Research, 261 Broadway, New York, N. Y.
PRATT, DANIEL W. .... 33 Wildwood St., Winchester, Mass.
RICH, MALCOLM .... Ferndale Rd., Wollaston, Mass.
SHUTE, GEORGE P. .... City Hall, Portsmouth, Ohio.
SKINNER, FENWICK F. .... 132 Lincoln Pl., Brooklyn, N. Y.
SMITH, CHESTER W. .... 2 Rector St., New York, N. Y.
SMITH, SIDNEY .... 255 Walnut St., West Lynn, Mass.
SNOW, FRANKLIN A. .... 79 Milk St., Boston, Mass.
STRADLING, DAVID W. .... 1932 Central Ave., Indianapolis, Ind.
THORPE, GEORGE H. .... 107 Merrimack St., Lowell, Mass.

DIED.

HOWLAND, ALBERT H. .... Died April 5, 1914.

LIBRARY NOTES.

RECENT ADDITIONS TO THE LIBRARY.

U. S. Government Reports.

Balsam Fir. Raphael Zon.

Cretaceous Deposits of Eastern Gulf Region. Lloyd William Stephenson.

Douglas Oil and Gas Field, Converse County, Wyoming. V. H. Barnett.

Geology of Long Island, New York. Myron L. Fuller.

Ground Water for Irrigation in Vicinity of Wichita, Kansas. O. E. Meinzer.

Lumber, Lath, and Shingles, 1912.

Magnetic Observations made by U. S. Coast and Geodetic Survey, July 1, 1911, to December 31, 1912. R. L. Faris.

Magnetic Observations made at U. S. Coast and Geodetic Survey Observatory at Sitka, Alaska, 1911 and 1912. Daniel L. Hazard.

Mineral Resources of U. S. for 1912. 2 vols.

Spirit Leveling in Kentucky, 1898 to 1913, inclusive. R. B. Marshall.

Spirit Leveling in Wyoming, 1896 to 1912, inclusive. R. B. Marshall.

Tests of Wooden Barrels. J. A. Newlin.

State Reports.

Massachusetts. Annual Report of Directors of Port of Boston for 1913.

Massachusetts. Special Report of Merrimac Valley Waterway Board, January, 1914. Gift of E. C. Sherman.

Massachusetts. Statutes Relating to Savings Banks.

New York. Regulation of Public Service Companies in Great Britain. Robert H. Whitten.

City and Town Reports.

Baltimore, Md. Annual Reports of Sewerage Commission for 1907–12, inclusive.

Belmont, Mass. Annual Report of Water Commissioners for 1913. Gift of C. W. Sherman.

Brookline, Mass. Annual Report of Water Board for 1913.

Clinton, Mass. Annual Report of Water Commissioners for 1913.

Concord, Mass. Annual Report of Board of Health for 1913.

Concord, Mass. Annual Report of Road Commissioners for 1913.

Concord, Mass. Annual Report of Water and Sewer Commissioners for 1913.

Haverhill, Mass. Annual Report of Water Commissioners for 1913.

Leominster, Mass. Annual Report of Water Board for 1913.

Medford, Mass. Annual Report of Water and Sewer Commissioners for 1913.

New Bedford, Mass. Annual Report of Engineering Department for 1913.

New Bedford, Mass. Annual Report of Water Board for 1913.

New York, N. Y. Preliminary Reports on Sewage Disposal, XV and XVI.

Plymouth, Mass. Annual Report of Water Commissioners for 1913.

Taunton, Mass. Annual Report of Water Board for 1913.

Woonsocket, R. I. Annual Report of Water Commissioners for 1913.

Miscellaneous.

American Hoist & Derrick Co. Catalog No. 106, 1914.

Life of J. Glancy Jones, 2 vols. Charles Henry Jones.

Municipal and Government Ice Plants in the U. S. and Other Countries. Jeanie Wells Wentworth.

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before the 25th of each month.)

United States Government. — NAVY DEPARTMENT. — *Navy Yard, Boston.* — Work is now in progress or new work is contemplated as follows:

WORK IN PROGRESS.

Mold loft floor for new supply ship.

Timber wharf extension at Naval Magazine, Hingham.

Reconstruction of Building No. 24: reinforced concrete.

Remodeling Building No. 77 for use as boat storage, including equipment with crane service.

Two 300-ft. radio towers on Naval Hospital Reservation, Chelsea. (Contract let.)

Building for central heating plant, Naval Hospital, Chelsea, to be built by day labor.

NEW WORK CONTEMPLATED.

Fireproof floor, sprinkler system and metal storage racks, pattern shop, Building No. 42.

Building ways for construction of new supply ship.

Commonwealth of Massachusetts. — METROPOLITAN PARK COMMISSION. — *Woburn Parkway.* — Work of construction of parkway from Pleasant St., Woburn, to Pond St., Winchester, is in progress.

Charles River Reservation, Lower Basin. — Work of constructing wall in Broad Canal and granolithic walks on the Embankment, between Cambridge Bridge and Beacon Street, is in progress.

Charles River Reservation, Upper Division. The work in progress consists of surfacing and paving the Anderson Bridge and approaches and of dredging upper portions of the basin from North Beacon St. to Watertown.

Nahant Beach Parkway. — Work of construction of wooden bulkhead in Lynn Harbor is in progress.

Nantasket Beach Reservation. — Work of construction of radial brick chimney 100 ft. high by 4 ft. 6 in. inside diameter, and a garbage and refuse destructor, is in progress.

METROPOLITAN WATER AND SEWERAGE BOARD. — *Sewerage Works.* — Work in Section 69, new Mystic Sewer, at Winchester, is in progress. Section 57A, in Chelsea and Revere, will be let soon.

Boston Transit Commission. — *Boylston Street Subway.* — The Boylston Street Subway extends from Kenmore St. near the intersection of Commonwealth Ave. and Beacon St. to the southwest corner of the Common near Park Square, a distance of about 8 000 ft. It is completed except for a small portion of the Massachusetts Ave. station, the stairways to the Copley Square station, the interior finish of the stations, and the connection with the Tremont St. Subway near Park Square. Work is in progress in all of these places. The Boston El. Ry. Co. is installing tracks, duct lines, lighting conduits, etc.

Dorchester Tunnel. — Section B includes the station in

Summer St., which will extend from near Washington St. east to Arch St. Most of the roof is in place and the earth core below is excavated. The invert, platforms and center wall are being put in, and work is progressing at the junction of the new station with the Summer station of the Washington St. Tunnel. New manholes, pipes and conduits are being laid over the roof in advance of the backfilling.

Section C is located in Summer St., and extends from near Arch St. to Dewey Square, a distance of about 1 018 lin. ft. About two thirds of its length is to be built by tunneling, working from several shafts. The structure is to be mainly of reinforced concrete. Work is in progress in the open-cut section between Otis and Devonshire Sts., also in the side drifts of the tunnel.

East Boston Tunnel Extension. — Section G extends in Court St. from Court Square westerly to Stoddard St. The structural work is practically completed. The construction of a part of the station under and east of the present Scollay Square station is in progress. Isaac Blair & Company, Inc., is the contractor.

Section H is located in and near Court and Cambridge Sts., extends from Stoddard St. to Staniford St. and includes the Bowdoin Square station. The buildings on Cambridge St. adjacent to the work are being underpinned and portions of the side walls of the tunnel have been built. Excavation in Court and Green Sts. is under way. An outlet sewer in Chardon St. is about completed.

Section J extends from Staniford St. to North Russell St. The incline in Cambridge St. has been built. Construction work between Staniford and Chambers Sts. is in progress. The walls of the tunnel have been built, most of the roof has been placed and the invert is being put in.

City of Boston. — Public Works Department, Highway Division, Paving Service. — Work is in progress on the following streets:

Cottage and Lubec Sts., from Gove St. to Porter St. Tar macadam.
Myrick St., from Coolidge Rd. to Easton St. Tar macadam.
Montebello Rd., from Washington St. to Brookside Ave. Tar macadam.

Park Lane St., from Park Lane to Olmstead St. Fence.
Porter St., from Bismarck St. to Amory St. Tar macadam.
Rexhame St., from Belgrade to Colberg Ave. Asphalt macadam.
Spring St., from Webster St. to the Charles River. Asphalt macadam.
Ballou Ave., from Willowwood St. to Woodrow Ave. Asphalt macadam.
Colonial Ave., from Talbot Ave. to New England Ave. Asphalt macadam.
Norfolk St., from Washington St. to the R. R. Bridge. Bitulithic.
Vassar St., from Washington St. to Kilton St. Tar macadam.
Wellington Hill St., from Blue Hill Ave. to Morton St. Asphalt macadam.
River St., Mattapan Square to the Hyde Park line. Tar macadam.
Binney St., from Longwood Ave. to Francis St. Asphalt macadam.
Roach St., from Dorchester Ave. to Pleasant St. Artificial stone.
St. Luke's Rd., from Brighton Ave. to Commonwealth Ave. Tar macadam.

New York, New Haven & Hartford Railroad. — Clinton, Mass. Elimination of Grade Crossings. Work on the Boston & Maine Railroad now in progress is the building of a passenger station.

Work on the N. Y., N. H. & H. R. R. now in progress is the building of a reinforced concrete arch at Main St. and the grading and excavation of Water and High Sts., and the work in connection with the drainage of the same. The steel bridge for the tracks across those of the B. & M. R. R. is in process of erection.

The Fore River Shipbuilding Co., Quincy, Mass., has the following new work in progress:

U. S. Battleship *Nevada*.
U. S. Submarine Tender *Fulton*.
Nine U. S. Submarine boats.
U. S. Torpedo Boat Destroyers *Cushing* and *Tucker*.
General Cargo Steamers *Atlantic* and *Pacific*.

Vol. I JUNE, 1914 No. 6

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

PAPER IN THIS NUMBER.

"Run-off from Sewered Areas." Report of Committee.

CURRENT DISCUSSIONS.

Paper.	Author.	Published.	Discussion Closes.
"Report on Sewerage Statistics."	Committee.	May.	Aug. 15.

REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on Wednesday, June 10, 1914, at 7.45 o'clock P.M., in

CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. L. W. Tucker will read a paper on "The Phosphate Rock Industry of Florida," illustrated with lantern slides.

MINUTES OF MEETINGS.

BOSTON, May 20, 1914. — A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order at 7.45 o'clock by the President, Mr. Harrison P. Eddy. There were 112 members and visitors present.

The reading of the record of the last meeting was, by vote, dispensed with, and the record was approved as printed in the May JOURNAL.

The Secretary reported for the Board of Government that the following had been elected to membership in the grades named:

Members — Benjamin Russell Chapman, James Michael Driscoll, Harold Daniel Haggett, Beardsley Lawrence, Oswell F. Mann, Clarence Edgar Morrow, Charles Eliot Nichols, Fred Dexter Sabin, Herbert L. Sherman and Charles Thomas Waring.

Junior — Edwin Daniel Hayward.

The appointment of the following committees by the Board of Government was also announced:

On Coöperation among the Engineering Societies in Boston — Charles R. Gow, Ralph E. Curtis and Irving E. Moultrop.

On Social Activities — Edmund M. Blake, chairman; Leslie H. Allen, George A. Carpenter, Herbert N. Cheney, Charles H. Eglee, Frederick C. H. Eichorn, John N. Ferguson, Clarence T. Fernald, Charles H. Gannett, Laurence B. Manley, Edwin R. Olin, George A. Sampson, Henry A. Symonds and Henry D. Woods.

On Papers and Program — Lewis E. Moore, chairman; Herbert R. Stearns, George C. Whipple, Walter W. Clifford, Edwin H. Rogers, DeWitt C. Webb, Robert S. Weston, Dana M. Wood and John P. Wentworth.

Mr. Wason, for the Committee on Excursions, announced that arrangements were under consideration for the entertainment of members of the Municipal Engineers of the City of New York, who were planning to visit Boston on June 20 next.

Mr. Blake, for the Committee on Social Activities, and Mr. Fay, for the Committee on Membership, made brief reports of the work in which these committees were engaged and asked for the active assistance of the members of the Society.

As the date for the next regular meeting of the Society falls on a holiday, June 17, on motion of the Secretary it was voted to hold the next meeting on Wednesday, June 10.

After an explanation from Prof. C. Frank Allen in relation to the vote passed at the last meeting authorizing the use of a portion of the Permanent Fund of the Society for current expenses, on his motion it was voted unanimously: That the Board of Government be authorized to use an appropriation from the Permanent Fund equivalent to the amount of the entrance fees for the fiscal year of 1913 and for the fiscal year of 1914; fifty-four members voting in the affirmative.

The President then introduced Mr. Edward S. Larned, who gave a most interesting talk on "The Manufacture of Portland Cement," illustrated by motion pictures.

At the close of the talk, a brief discussion was held, after which the meeting adjourned.

S. E. Tinkham, *Secretary.*

SANITARY SECTION.

Boston, Mass., May 11, 1914. — A special meeting of the Sanitary Section of the Boston Society of Civil Engineers was held this evening at the Engineers Club.

It was called for the purpose of giving the members an opportunity to meet Mr. Arthur J. Martin, sanitary expert of London, England, who postponed the date of his sailing from this country to attend this meeting. Mr. Martin, a member of the Institution of Civil Engineers, is a past president of the Institute of Sanitary Engineers, which office is now held by Mr. John D. Watson, of Birmingham, with whose work many of our members are acquainted and who was invited to attend this meeting but was unable to prolong his visit in this country on account of pressing business engagements. Many of the members of the Sanitary Section are quite familiar with Mr. Martin's work in sanitary engineering, much of which has been in the field of sewage disposal. His book entitled "The Sewage Problem" has proved a valuable digest of the voluminous evidence taken by the Royal Commission on Sewage Disposal and published in its earlier reports. Mr. Martin is at the head of the Health Week movement which extends throughout the United Kingdom.

Besides the principal guest of the evening, other guests were Dr. Otto Haehnle, of Germany, who is making a study of the textile industries in this country; and Mr. R. G. Perkins, of the Department of Hygiene, Western Reserve University, Cleveland, Ohio. Dr. Haehnle came as the guest of Mr. S. Everett Tinkham, and Mr. Perkins as the guest of Prof. George C. Whipple.

The meeting was called to order at 7.30 o'clock by Chairman Bertram Brewer. After a few introductory remarks, the Chairman called upon Mr. Harrison P. Eddy, President of the Society, to extend a welcome to the guests of the evening.

The Chairman then introduced as the speaker of the evening, Mr. Arthur J. Martin, who gave a most interesting talk along the lines of "The Development and Present Status of Sewage Purification in England."

In the course of his remarks, Mr. Martin reviewed the various stages through which the science of sewage treatment has passed in England, and pointed out the salient features of each and their present status. He referred especially to the "contact bed" as never having been given a fair show to demonstrate its possibilities.

In speaking of the "hydrolytic tank" and the Hampton doctrine, Mr. Martin referred to a form of colloidal bed or upward flow filter which he has been using in his private practice. This bed is constructed on a false floor, similar to the floors used for trickling filters, and is made up of hexagonal earthenware tile set on end to a depth of about 4 ft., with adjacent tiles cemented together on the sides, forming in plan a sort of honeycomb effect. The sewage is admitted at the bottom and flows vertically upward and out at the top with a slow velocity.

Mr. Martin also spoke briefly of the work which had been done in Chicago by the commission, of which he was a member, retained by the Chicago Real Estate Board to study the sanitary problems of the city. One feature of special interest in the studies was the action of the Chicago Drainage Canal, and the varying amounts of dissolved oxygen at different points along its course, which indicated the progress in the oxidation of the organic matter.

Mr. Martin spoke in appreciation of the work done by the Massachusetts State Board of Health at the Lawrence Experiment Station, and of the value to sanitary engineers of the results there obtained.

The speaker also related briefly some of the events connected with " Health Week " which is growing in importance in England. This week is set apart as a time for devoting all energies toward educating the people in health matters. Definite instruction is given in the schools and churches, through lectures and the daily newspapers, magazines and other agencies, in an endeavor to awake the average citizen to a realization of what should be done in hygiene and sanitation in order to assist in relieving some of the unhealthful conditions existing in thickly settled communities.

At the close of Mr. Martin's address, Mr. F. P. Stearns told of some of his own observations in regard to the purifying action of rivers and the variation in the amounts of dissolved oxygen in the water.

Dr. Frederic Bonnet, Jr., was called upon by the Chairman to speak for the younger men in the section. At the close of his remarks, Dr. Bonnet moved a rising vote of thanks to Mr. Martin for his courtesy in speaking before the section, and best wishes for a pleasant voyage, which was carried with enthusiasm.

Prof. George C. Whipple spoke of his own interest in the address of the evening, and especially in the idea of a " Health Week," which he stated was far ahead of the American " Clean-Up Week."

The meeting was preceded by a dinner served in one of the private dining rooms of the club, at which 25 members and guests were present.

There were 46 present at the meeting. Adjourned at 9 o'clock.

FRANK A. MARSTON, *Clerk.*

APPLICATIONS FOR MEMBERSHIP.

[May 28, 1914.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

BERRY, CHARLES RICHARD, Roslindale, Mass. (Age 29, b. Jamaica Plain, Mass.) Graduate of Charles Sumner Grammar School, Roslindale, Mass., 1899; of West Roxbury High School, 1903; of International Correspondence Schools, civil engineering course, 1914. From 1906 to 1907, with Aspinwall & Lincoln, civil engineers; from 1907 to 1908, with Charles River Basin Comm. on construction of dam; from 1908 to 1910, with Boston Elevated Ry. Co., on construction of Cambridge, Main St. subway; from 1910 to 1912, with Metropolitan Water Board; from 1912 to date, with Boston Transit Comm. Refers to E. S. Davis, W. W. Davis, J. B. Flaws, L. B. Manley, R. E. Rice, and S. S. von Loesecke.

HOSMER, GEORGE LEONARD, Woburn, Mass. (Age 39, b. Lynn, Mass.) Attended Massachusetts Institute of Technology from 1893 to 1897; teacher at Massachusetts Institute of Technology from 1897 to date; during summers engaged as follows: From 1897 to 1900, surveys for Massachusetts Topographical Comm.; 1901, member Astronomical Expedition to Sumatra; 1902, Charles River Dam; 1903, New York Water Supply; 1904, Stony Brook aqueduct, Cambridge; 1905, Magnetic Expedition to Labrador (Carnegie Institute); 1906, survey Conn.-Mass. Boundary Line; 1907, Lynn Water Supply; 1908, Park Comm. of Rhode Island; 1909, surveys on Blackwater River; 1910, surveys on Deerfield River; 1911, surveys on grade crossings at Taunton, Mass. Author of "Text-book on Practical Astronomy" and of

"Azimuth"; joint author with C. B. Breed of "Principles and Practice of Surveying." Refers to C. F. Allen, C. B. Breed, A. E. Burton, A. G. Robbins, C. M. Spofford, and H. B. Wood.

HOWARD, JOHN WARDWELL, Boston, Mass. (Age 35, b. Providence, R. I.) Graduate of Massachusetts Institute of Technology, civil engineering course, 1903. During summer of 1902, with Pennsylvania R. R. Co. as rodman; summer of 1903, with Commission on Additional Water Supply, city of New York, as field assistant; summers of 1904 to 1909, transitman on town boundary survey of Massachusetts; January to October, 1912, assistant engineer, Costa Rica-Panama Boundary Survey; from 1903 to 1905, assistant in civil engineering; from 1905 to 1913, instructor in civil engineering; from 1913 to date, assistant professor of topographical engineering, Massachusetts Institute of Technology. Associate member of American Society of Civil Engineers, elected March, 1913. Refers to C. B. Breed, A. G. Robbins, G. E. Russell and C. M. Spofford.

LANE, EDWARD PERCY, Manchester, Mass. (Age 36, b. Manchester, Mass.) Graduate of Massachusetts Institute of Technology, civil engineering course, 1898. From November, 1898, to May, 1899, rodman and draftsman with Chicago Great Western Ry., St. Paul, Minn.; from May, 1899, to May, 1903, draftsman and checker on shop drawings for structural steel work at Elmira, N. Y., plant of American Bridge Co.; from May, 1903, to July, 1903, steel designer on power-houses with Westinghouse, Church, Kerr & Co., New York City; from July, 1903, to May, 1911, with New York Central & Hudson River Railroad, New York City — during first two years on miscellaneous bridge and building work, during last six years as chief draftsman and assistant engineer in charge of steel design for Grand Central Yard Improvements; from September, 1911, to date, chief draftsman in structural department of Boston & Maine Railroad, on bridge and building design. Refers to R. C. Allen, B. W. Guppy, J. C. Moses and J. J. Rourke.

STONE, LEO SOLOMON, Roxbury, Mass. (Age 27, b. Boston, Mass.) Graduate of Massachusetts Institute of Technology, 1909, degree of B.S.; 1909, inspector, city of Springfield, new water supply; 1910, transitman with Charles River Basin Comm.; 1911, structural detailer with New England Structural Co., surveyor with United States War Department; 1911–12, inspector on new street work for city of Boston; from 1912 to date, with Boston Transit Comm. as inspector on Boylston St. subway. Refers to H. L. Crocker, F. C. H. Eichorn, J. T. Frame, G. W. Lewis and L. B. Manley.

WIRES, HARRISON PARKER, Rockport, Mass. (Age 46, b. North Brookfield, Mass.) Graduate of Worcester Polytechnic Institute, 1890. In 1892 resident engineer, St. Albans, Vt., water works and Middleboro, Mass., sewers; 1893, assistant engineer with E. Worthington, Dedham, on water supply investigations and construction; 1894, resident engineer on construction, Rockport, Mass., water supply; 1895, assistant engineer on surveys for Plymouth County Railroad, resident engineer on construction, sewerage system at Medfield Insane Asylum and of New England Breeders' Racetrack at Readville; 1896, superintendent of construction, water supply at York Beach;

Me., chief of party for Massachusetts Highway Comm.; 1897, inspector of heavy pipe laying under Mystic River for Metropolitan Water Board; 1898, resident engineer on construction, water supply for North Andover, Mass.; 1899, superintendent of construction, water supply for Watertown, Conn.; from 1900 to 1903, inspector and junior engineer, United States Engineering Department, on breakwater construction and hydrographic surveys; 1904, superintendent of construction, water supply for Wilton, N. H.; 1905, chief of party for Fitchburg & Lowell Railroad, superintendent of construction, hydro-electric plant at Sanford, Me.; 1906, superintendent of construction, hydro-electric plants at Sanford and West Buxton, Me.; 1907, construction engineer, United States Reclamation Service; 1907–08, assistant engineer with Metcalf & Eddy on Finance Comm. investigations; 1908–10, division engineer on construction of sewers at Louisville, Ky.; 1911, assistant engineer with Metcalf & Eddy on Marlboro, Mass., sewage disposal plant; 1912, assistant engineer, New Bedford City Engineering Department; 1913 to date, civil and consulting engineer, 119 Main St., Gloucester, Mass. Refers to W. T. Barnes, H. P. Eddy, C. H. Eglee, R. K. Hale, T. T. H. Harwood, J. H. Kimball, A. M. Lovis, E. H. Rockwell, C. W. Sherman, R. S. Weston and Erastus Worthington.

EMPLOYMENT BUREAU.

THE Board of Government has established an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

MEN AVAILABLE.

141. Age 26. Has had five years of secondary school work, three years of higher mathematics in Lynn Evening High School, including trigonometry, etc., one season's private instruction from Mr. Wm. Granstein of Harvard, and one season at the Boston Franklin Union. Has had one year's experience in land and railroad surveying, calculating of parcel areas, and precise level work with Boston Elevated Railway Co. and Boston & Maine Railroad; also four years' experience in mechanical and electrical work with General Electric Co. of Lynn. Desires position as transitman or rodman. Salary desired, $15 per week.

197. Age 18. Graduate of Mechanic Arts High School, 1913. Has had no practical experience, but has had one year's school experience in sur-

veying. Desires position as rodman in civil engineer's or surveyor's office. Will start at low salary.

233. Age 21. Student at Massachusetts Institute of Technology for three years; expects to finish later. From October, 1913, to January, 1914, with Massachusetts Highway Comm. as rodman. Desires position as rodman or junior draftsman. Salary desired, $50 per month.

234. Age 20. Preparatory school graduate. Has had four summers' experience with C. A. Mason, Cambridge, Mass., and one with J. W. Dotton, Medford, Mass. Desires position as transitman or rodman. Salary desired, $10 per week.

235. Age 43. Graduate of Phillips Academy, Andover, Mass., 1890, and of Thayer School of Civil Engineering, Dartmouth College, 1895. Experience includes sewer inspection, cement testing, and inspection of fortification work; also two years with Rutland-Canadian Railway, two years with Buffalo, Rochester & Pittsburg Railway, and one year on sewer construction, Mohawk, N. Y., as resident engineer; was for about five years regular inspector for Associated Factory Mutual Fire Insurance Companies. Desires outside position.

LIST OF MEMBERS.

ADDITIONS.

Driscoll, James M. .... Chestnut Hill, Mass.
Haggett, Harold D. .... 303 North Station, Boston, Mass.
Sherman, Herbert L. .... 12 Pearl St., Boston, Mass.
Waring, Charles T. .... Sandwich, Mass.

CHANGES OF ADDRESS.

Allen, Lawrence H., Division of Valuation, Eastern Dist., Interstate Commerce Comm., Washington, D. C.
Badger, Frank S., care J. G. White & Co., Ltd., 9 Cloak Lane, Cannon St., London, E. C., England.
Barnes, T. Howard .... Room 1646, 17 Battery Pl., New York, N. Y.
Bickford, John W., U. S. Engineers Office, Dam No. 16, Ohio River, Bens Run, W. Va.
Hathaway, Erwin O. .... State House, Augusta, Me.
Hurd, Stephen P. .... 644 Adams St., East Milton, Mass.
Iverson, Thomas .... Chamber of Commerce Bldg., Torrington, Conn.
Jaques, William H. .... Little Boar's Head, N. H.
Oakes, John J., Chief Engineer, Ferrocarril de S. y S., Sanchez, Republica Dominicana.
Perkins, Clarence A. .... 57 High St., Malden, Mass.
Rice, James .... Forest Hills Inn, Forest Hills, Long Island, N. Y.
Rice, Ralph E. .... 119 Magnolia St., Dorchester, Mass.

SAWTELLE, HARRY F. . . . . .Clifton, Mass.
TUCKER, FRANCIS C. . . . . 1938 Home Ave., Chicago, Ill. (Rogers Park.)
WADE, CLIFFORD L. . . . . .292 Palmer St., New Bedford, Mass.
WONES, BERNARD B. . . . . .592 University St., Montreal, Canada.

LIBRARY NOTES.

Recent Additions to the Library.

U. S. Government Reports.

Estimates of Population, 1910–14.

Fourth General Adjustment of Precise Level Net in United States and Resulting Standard Elevations. William Bowie and H. G. Avers.

Rocky Mountain Mine Timbers. Norman de W. Betts.

State Reports.

Connecticut. Annual Report of Public Utilities Commission for 1912–13.

Iowa. Use of Iowa Gravel for Concrete. T. R. Agg and C. S. Nichols.

Massachusetts. Annual Report of Harbor and Land Commissioners for 1913.

Michigan. Annual Report of State Board of Health for 1912.

New Jersey. Annual Report of State Board of Health for 1912.

City and Town Reports.

Boston, Mass. Annual Reports of Finance Commission, Vols. V to IX, 1909 to 1913 inclusive.

Concord, N. H. Annual Report of Water Department for 1913.

Fitchburg, Mass. Annual Report of City Engineer for 1913.

New York, N. Y. Preliminary Report on Disposal of New York's Sewage, No. XVII.

Newton, Mass. Annual Report of Water Commissioner for 1913.

St. Paul, Minn. Annual Report of Water Commissioners for 1913.

Worcester, Mass. Annual Report of Superintendent of Sewers for 1913.

Miscellaneous.

American Water Works Association. Proceedings for 1913.

American Institute of Mining Engineers. Transactions, Vol. XLV.

Massachusetts Institute of Technology. Reports of Sanitary Research Laboratory, Vols. IV and VI to IX inclusive.

Mexican Institute of Mining and Metallurgy. Transactions, Vol. I, 1909–1910. Gift of Massachusetts Institute of Technology Library.

Municipal Engineers of City of New York. Valuation of Public Utilities. Nicholas S. Hill, Jr.

New York Stock Exchange. Brief and Reply Brief Submitted to Senate Committee on Banking and Currency, March, 1914.

Permanent International Association of Congresses of Navigation. Securing High Efficiency of Pier or Quay Walls in Loading or Discharging Miscellaneous Cargoes. H. McL. Harding. Works of Improvement on the Rupel between Wintham and Its Junction with the Scheldt. H. Vander Vin. Programmes of Proceedings, etc., of XII International Navigation Congresses, 1885–1912. Shipbuilding from Its Beginnings, 3 vols.

Mr. Robert Spurr Weston has been instrumental in obtaining for the Society the above-mentioned reports of the Sanitary Research Laboratory of the Massachusetts Institute of Technology. Mr. Weston was unable to procure Vols. I, II, III and V, as the supply of these volumes was exhausted. Can any of our members supply them?

Can any member furnish the library with a copy of Mallard's Report on Vibration in London Subways, or give us information as to where one can be obtained?

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before the 25th of each month.)

United States Government. — Navy Department. — *Navy Yard, Boston.* — Plans for building ways for supply ship are completed.

Commonwealth of Massachusetts. — Metropolitan Water and Sewerage Board. — *Water Works.* — Work is now in progress on the construction of a water pipe tunnel under Chelsea Creek between East Boston and Chelsea. The tunnel is located about 800 ft. above the Meridian St. Bridge, and is 640 ft. in length, including the two vertical shafts, each about 60 ft. deep, located at the sides of the channel.

The tunnel will be excavated about 9 ft. in diameter and will be temporarily supported by a brick masonry wall 8 in. thick until the 42-in. pipe is laid, when the space between the pipe and the brick work will be filled solidly with concrete to protect the pipe from corrosion. The 42-in. water pipes are 1.8 ins. thick and are provided with special lead grooves. The joints are to be made with lead wool and will be calked on both the inside and outside of the pipe.

The work also includes the building of a timber bulkhead about 100 ft. in length, the placing of 7 000 cu. yds. of earth filling, and the removal of two existing lines of 24-in. cast-iron pipe from the bottom of the channel.

The amount of the contract is estimated at about $60 000.

Metropolitan Water and Sewerage Board. — *Sewerage Works.* — Work in Section 69, new Mystic Sewer, at Winchester, is in progress.

Metropolitan Park Commission. — The following work is in progress:

Blue Hills Reservation. — Construction of two reinforced concrete bath-houses at Houghton's Pond.

Charles River Reservation, Upper Division. — Surfacing and paving the Anderson Bridge and approaches. Dredging river from North Beacon Street to Watertown.

Charles River Reservation, Lower Basin Section. — Construction of granolithic walks on the embankment between Cambridge Bridge and Beacon St.

Middlesex Fells Parkway. — Construction of West Border Road, Malden.

Nahant Beach Parkway. — Construction of wooden bulkhead in Lynn Harbor.

Nantasket Beach Reservation. — Construction of garbage and refuse destructor.

Woburn Parkway. — Construction of parkway from Pleasant St., Woburn, to Pond St., Winchester.

General. — Reconstruction, resurfacing, and surface treatments with bituminous materials of roadways in various divisions.

Directors of the Port of Boston. — *Dry Dock.* — Contract for dry dock 1 200 ft. long over all, 120 ft. wide on bottom of sill, and 35 ft. over sill at mean low water is now advertised, bids to be received June 15. This work includes dredging approach channel and turning basin and building approach piers.

The pumping machinery and superstructure of pump house and the caisson will be let in separate contracts.

Bulkhead. — Over 3 000 lin. ft. of bulkhead finished and 1 000 ft. more is 50 per cent. completed.

Viaduct. — Form work on concrete slab for roadway is now in progress.

Railroad Yard. — Laying drains and grading for tracks is being done.

Heating Plant. — Building is completed; also chimney stack built by the Custodis Company; four boilers are being erected and piping nearly completed.

Commonwealth Pier No. 5. — Headhouse is about 75 per cent. completed and the westerly freight shed is nearly finished.

Commonwealth Pier No. 1, East Boston. — Plans and specifications are practically finished for the improvement of the pier, and bids will be received for this work on June 16.

Boston Transit Commission. — *Boylston Street Subway.* — The subway structure is completed except for a small portion of the Massachusetts Ave. station and the connection with the Tremont St. Subway near Park Square. Work is in progress at these places. Work on the interior finish of the two stations is also in progress. The Boston Elevated Railway Company is engaged in installing duct lines, lighting conduits, etc.

Dorchester Tunnel.— Section B includes the station in Summer St., which will extend from near Washington St., east to Arch St. Most of the roof is in place and the earth core below is excavated. Work is progressing at the junction of the new station with the Summer Station of the Washington St. Tunnel and on the inclined elevator shafts within buildings at the corners of Hawley St. and Chauncy St.

Section C is located in Summer St. and extends from near Arch St. to Dewey Square, a distance of about 1 018 lin. ft. About two thirds of its length is to be built by tunneling, working from several shafts. The structure is to be mainly of reinforced concrete. Work is in progress on both the open cut and tunnel sections.

East Boston Tunnel Extension. — See JOURNAL for May.

City of Boston. — PUBLIC WORKS DEPARTMENT, HIGHWAY DIVISION, PAVING SERVICE. — Work is in progress on the following streets:

Cottage St., from Gove St. to Porter St. Tar macadam.

Harvard Ave., from Commonwealth Ave. to Cambridge St. Bitulithic.

St. Luke's Rd., from Brighton Ave. to Commonwealth Ave. Tar macadam.

Jess St., from Porter St. about 220 ft. southerly. Bituminous macadam.

Spring St., from Webster St. to the Charles River. Asphalt macadam.

Clermont St., from Bailey St. to Fuller St. Asphalt macadam.

Ballou Ave., from Willowwood St. to Woodrow Ave. Asphalt macadam.

Colonial Ave., from New England Ave. to Talbot Ave. Asphalt macadam.

Norfolk St., from Washington St. to the railroad bridge. Bitulithic.

Vassar St., from Washington St. to Kilton St. Tar macadam.

Wellington Hill St., from Blue Hill Ave. to Morton St. Asphalt macadam.

Potosi St., from Mt. Ida Rd. to Percival St. Tar macadam.

Wilmore St., from Blue Hill Ave. to Norfolk St. Asphalt macadam.

Seaver St., from Walnut Ave. to Humboldt Ave. Excavating and grading.

Binney St., from Francis St. to Longwood Ave. Asphalt macadam.

Gayland St., from West Cottage St. to Judson St. Tar macadam.

Sachem St., near Parker Hill Ave. Retaining wall.

Pleasant St., from Washington St. to Eliot St. Wood block pavement.

City of Fitchburg. — SEWAGE DISPOSAL COMMISSION. — *Sewage Disposal Plant.* This consists of (1) five Imhoff tanks each about 90 ft. long, 30 ft. wide and 26 ft. deep, covering a rectangular area of 150 x 90 ft. These tanks are being constructed of concrete with reinforcing rods and structural steel. (2) Two acres of sprinkling filters with stone 10 ft. deep. The filter floor is constructed of concrete with wire reinforcement. Circular segmental troughs in the floor are covered with cement bricks on which the broken stone is placed. The distribution pipes will be laid just below the surface of the filter and will be supported by the stone. (3) Four circular secondary settling tanks each 30 ft. in diameter and 24 ft. deep situated between the sprinkling filter and the river. (4) About 0.4 acre of sludge drying beds. (5) A brick laboratory and general building 33 ft. 8 ins. by 43 ft. 8 ins. (6) Minor appurtenant works including pump house, dosing chamber, Venturi meter, overflow chamber and macadam roadways.

Construction was begun in 1913 and at present the contract is about one half completed. All features of the work are in an

interesting stage of progress and will be for the next three or four months. The contractors are R. H. Newell Co. and N. S. Brock.

New York, New Haven & Hartford Railroad. — Clinton, Mass. Elimination of Grade Crossings. — Work on the B. & M. R. R. now in progress is the erection of a passenger station and the development of the transfer yard between the two railroads. Work is soon to be commenced for the final excavation of the B. & M. roadbed by steam shovel.

Work on the N. Y., N. H. & H. R. R. is the building of a reinforced concrete arch at Main St. and the grading, surfacing, etc., of Water and High Sts. The steel bridge for the tracks across the B. & M. R. R. has been completed and the erection of the final span of the bridge which will carry the New Haven tracks over Water St. is in progress, which, when done, will complete the steel work.

Aberthaw Construction Company. — Boston, Mass. — At the fish pier the structural steel for the eight-story cold storage warehouse is nearly erected, and insulating cork is being placed in the ice storage room.

South Manchester, Conn. — The foundations are nearly finished for the dye house and weave shed under construction for Cheney Brothers, silk manufacturers.

Great Works, Me. — Aberthaw Construction Company will build an addition to the wood pulp mill of the Penobscot Chemical Fibre Company, the new work consisting of three digesters, blow pits, acid plant and one paper machine building.

The Fore River Shipbuilding Co., Quincy, Mass., has the following new work in progress:

U. S. Battleship *Nevada.*

U. S. Submarine Tender *Fulton.*

Nine U. S. submarine boats.

U. S. Torpedo Boat Destroyers *Cushing* and *Tucker.*

Vol. I SEPTEMBER, 1914 No. 7

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

PAPERS IN THIS NUMBER.

"The Mechanics of Reinforced Concrete." C. A. P. Turner.

(To be presented September 16, 1914.)

Discussion of "Boston Foundations," with Author's Closure.

Current Discussions.

Paper.	Author.	Published.	Discussion Closes.
"Run-off from Sewered Areas."	Committee.	June.	Oct 15.

REGULAR MEETING.

A regular meeting of the Boston Society of Civil Engineers will be held on Wednesday, September 16, 1914, at 7.45 o'clock P.M., in

CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. C. A. P. Turner will read a paper on "The Mechanics of Reinforced Concrete under Flexure in Beam and Slab Types." This paper is printed in this number of the Journal.

MINUTES OF MEETINGS.

BOSTON, June 10, 1914. — A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order at 8.20 o'clock by Vice-President Charles R. Gow. There were present 63 members and visitors.

In the absence of the Secretary, on motion of Mr. C. W. Sherman, Mr. J. E. Carty was elected Secretry *pro tem.*

The reading of the record of the last meeting was, by vote, dispensed with, and the record was approved as printed in the June JOURNAL.

The Secretary *pro tem.* reported for the Board of Government that the following had been elected to membership in the grades named:

Members — Alexander S. Ackerman, George W. Burpee, Lester F. Ellis, Carl C. Enebuske, Charles A. French, Howard A. Gray, Royal L. Mead, Samuel L. Milton, Edward D. Storrs, George Taylor and Alexander K. Williams.

Junior — Ashley Q. Robinson.

The Vice-President then introduced as the speaker of the evening, Mr. Lester W. Tucker, who gave an interesting talk, illustrated with lantern slides, on "The Phosphate Rock Industry of Florida," a novel subject to most of the members present.

At the close of the talk a brief discussion was held, after which the meeting adjourned.

JOHN E. CARTY, *Secretary pro tem.*

SANITARY SECTION.

FITCHBURG, MASS., June 3, 1914. — The regular June meeting of the Sanitary Section of the Boston Society of Civil Engineers was held to-day as an excursion to the Fitchburg Sewage Disposal Works.

About half the party left Boston on the 11.15 A.M. train for Fitchburg, arriving at 12.30 o'clock. The remainder arrived by various routes, a number coming by automobile.

At the Fitchburg station the party was met by representatives of the City and the Sewage Disposal Commission, and conveyed to a point near the Disposal Works in a special electric car provided by the City.

An excellent buffet lunch was served in the new laboratory building, at which the members and friends, in number about 65, were the guests of the Sewage Disposal Commission. Following the luncheon the party was called together in the main office of the laboratory by Chairman Bertram Brewer. His Honor Mayor Cook spoke briefly, extending the welcome of the City to the Section, and expressing the hope that the trip would prove not only very enjoyable but also profitable from an engineering point of view.

The chairman of the Sewage Disposal Commission, Arthur H. Lowe, and the chief engineer, David A. Hartwell, were also called upon to speak.

A formal vote was passed, extending to the city officials and members of the Sewage Disposal Commission the thanks and appreciation of the Section for the courtesies shown.

The party then broke up into small groups, to make an inspection of the sewage disposal works. Pamphlets were provided, giving briefly the more important facts in regard to the design and construction of the works. The pamphlets included three plans showing details of the Imhoff sedimentation tanks, the sprinkling filters and the secondary settling tanks.

The construction work was at a stage to show to best advantage the methods of construction, materials and general appearance of the work when finished. The contractors for the plant, R. H. Newell & Co. and N. S. Brock, kindly arranged to have many of the different kinds of work under way, and ample facilities were provided for inspecting all parts of the construction.

The application of cement mortar to the thin partition walls in the Imhoff tanks proved to be one of the most interesting features. The mortar was being applied to the "Rib-Trus"

metal reinforcement by means of the cement gum. The false-floor system of the sprinkling filters also attracted considerable attention.

About three o'clock, at the invitation of the City, the party, to the number of 38, boarded a special electric car for a run to Whalom Park in Lunenburg. About fifteen minutes were allowed, to stroll about the park. From there the car returned to the City, leaving some of the party at the railroad station, and then went through the City, passing some of the sewer construction work, and took the party, then reduced to about twenty-five, on a nine-mile ride to Wachusett Lake, at the foot of Wachusett Mountain. The scenery along the road was beautiful and the ride was thoroughly enjoyed by all who went. The trolley trip also afforded the members a chance to see two of the reservoirs of the City's water-supply system. After a short stop at the lake, the party returned to Fitchburg in time for the 6.22 train for Boston.

F. A. Marston, *Clerk.*

APPLICATIONS FOR MEMBERSHIP.

[August 28, 1914.]

The By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

Ambrose, George Clifford, Boston, Mass. (Age 31, b. Boston, Mass.) Attended Rice Training School and Franklin Union. Employed by Edison Co., Cable Department, chiefly in State Street tunnel during construction of same; with Boston Consolidated Gas Co. for twelve years, during which time he has served as superintendent of construction in building of warehouse for appliance department and in building of power plant at Central Station; also as assistant district foreman in main and service departments, inspector on Stony Brook sewer construction in Roxbury, and as yard foreman at Central Station Plant, which position he still holds. Refers to H. N. Cheney, H. W. Dyer, J. A. Gould and D. S. Reynolds.

Dingman, Charles Francis, Palmer, Mass. (Age 29, b. Jersey City, N. J.) Received education in public schools of Jersey City, at Cooper Union, New York City, and from I. C. S. and A. S. of C. courses in advertising, chemistry, architectural engineering, mechanical drawing and fire prevention engineering. From June, 1899, for about three years in office of Charles W. Leavitt, Jr., C.E., New York City; then worked as draftsman with Passmore-Meeker Co. (granite and marble), Newark, N. J., until dissolution of that company; was for two years with Del., Susq. & Schuylkill R. R. Co. and later, until 1905, with E. M. Waldron & Co., builders, Newark, N. J., as clerk of works; with Merrick Fireproofing Co., 1 Broadway, New York City, as quantity estimator from 1905 to December, 1909, as contracting engineer from that date to May, 1912, and as secretary from that time till May, 1914; is now engineer with Flynt Building and Construction Co., Palmer, Mass.

Ell, Carl Stephens, Roslindale, Mass. (Age 27, b. Staunton, Ind.) Graduated from DePauw Academy, 1906, and from DePauw University, 1909, with degree of A.B.; received degrees of S.B. and M.S. from Mass. Inst. of Technology in years 1911 and 1912 respectively. Inspecting engineer, N. Y. State Department of Health, during summers of 1911 and 1914; instructor Mass. Inst. of Technology summer camp, summer of 1912; part time instructor in civil engineering, Coöperative Engineering School of Boston Y. M. C. A., 1910–12; from 1912 to date, in charge of Civil Engineering Department of that institution and since spring of 1914 has been assistant dean. Refers to C. B. Breed, L. E. Moore, Dwight Porter and C. M. Spofford.

French, Arthur Willard, Worcester, Mass. (Age 46, b. Battle Creek, Mich.) Attended common and high schools, Milford, N. H.; student at Dartmouth College for three years and at Thayer School of Civil Engineering, Dartmouth College, for two years, receiving degree of C.E. in 1892. From 1892 to 1894, engineer in charge of construction, Platte River Paper Mills, Denver, Colo.; from 1894 to 1895, draftsman and bridge designer with Union Pacific, Denver & Gulf R. R.; from 1895 to 1898, associate professor of civil engineering, Thayer School of Civil Engineering; from 1898 to 1899, engaged in business and engineering, Niagara Falls, N. Y.; from 1899 to

date, professor of civil engineering, Worcester Polytechnic Institute; has done limited amount of consulting work on steel and concrete structures during past fifteen years. Refers to C. M. Allen, Frederic Bonnet, Jr., I. N. Hollis, A. B. MacMillan, F. B. Sanborn and L. C. Wason.

LYONS, TIMOTHY RICHARD, Manchester, N. H. (Age 28, b. Manchester, N. H.) Graduate of Worcester Polytechnic Inst., 1910, in civil engineering course. Has been with Aberthaw Construction Company for four years, mostly in charge of some department of construction; for two years past has been superintendent in charge of building construction for this firm and is now in charge of construction of Commonwealth Ice and Cold Storage Plant, New Fish Pier, Boston. Refers to C. M. Allen, J. A. Garrod, A. B. MacMillan and L. C. Wason.

MACONI, GAETANO, Newton Center, Mass. (Age 22, b. Somerville, Mass.) Has completed three years' work at Mass. Inst. of Technology; no engineering experience. Refers to C. F. Allen, C. B. Breed and A. G. Robbins.

MAILEY, JOHN BRUCE, Lynn, Mass. (Age 28, b. Lynn, Mass.) Graduate of Tufts College, 1910, structural engineering course; student at Harvard Graduate School of Civil Engineering, September, 1911, to June, 1912. Structural draftsman with the following: Riter-Conley Mfg. Co., Pittsburgh, Pa., October, 1910, to January, 1911; New England Structural Co., January to April, 1911; Poste McCord, New York City, April to July, 1911, and January to August, 1912; American Bridge Co., Pencoyd, Pa., August to September, 1911; from August, 1912, to date, with B. & M. R. R. Co.; designing draftsman in bridge department until May, 1914; since that date in department of valuation. Refers to S. L. Conner, B. W. Guppy, E. H. Rockwell and F. B. Sanborn.

PEASLEE, DANA NEWTON, Lynn, Mass. (Age 26, b. New London, N. H.) Graduate of University of Maine, civil engineering course, 1911. Rodman with city engineer of Lynn during summer of 1909 and part of summer of 1910; June 15 to June 25, 1911, instructor in advanced surveying at University of Maine; June, 1911, to June, 1914, with B. & M. R. R. Co. as draftsman on steel and concrete; is now computer on valuation work for same company. Refers to H. S. Boardman, S. P. Coffin, F. C. Shepherd and W. L. Vennard.

ROBINSON, HAROLD LONG, Cambridge, Mass. (Age 25, b. Boston, Mass.) From October, 1907, to June, 1911, student at Mass. Inst. of Technology. Did summer work as follows during course at Institute: 1907, rodman with B. & M. R. R. Co.; 1908, transitman for town of Winchester, Mass.; 1909, with Professor Hosmer on plane table work in Vermont; 1910, assistant engineer with J. B. Ferguson, Hagerstown, Md. From June, 1911, to November, 1912, with Aberthaw Construction Co.; November, 1912, to date with Swift & Co. as construction superintendent on building work. Refers to C. B. Breed, L. E. Moore and C. M. Spofford.

RUNELS, RALPH EARLE, Lowell, Mass. (Age 27, b. Lowell, Mass.)

Graduate of Mass. Inst. of Technology, 1911, civil engineering course. From September, 1911, to January, 1912, with Aberthaw Construction Co. as carpenter foreman and steel foreman; from January, 1912, to February, 1913, with F. W. Dean, Inc., first as general inspector of work and later as resident engineer in charge of work for cold storage plant in Portland, Me.; February, 1913, to date, with Electric Bond and Share Co., New York City, in hydraulic department, as designer of hydro-electric power plants. Refers to C. B. Breed, F. W. Dean, H. S. French, L. E. Moore, Dwight Porter and C. M. Spofford.

Sawyer, George Summers, Brighton, Mass. (Age 24, b. Charlestown, Mass.) Graduate of Mass. Inst. of Technology, 1912, civil engineering course. From June to August, 1913, with Prof. C. M. Spofford as computer and draftsman; from August to October, 1912 and 1913, assistant at Technology Summer Surveying Camp; from October to June, 1912–13 and 1913–14, assistant in civil engineering department, Mass. Inst. of Technology; is now transitman on construction work at Fall River, Mass., for Barrows & Breed, of Boston. Refers to C. F. Allen, H. K. Barrows, C. B. Breed, A. L. Shaw and C. M. Spofford.

Smith, Arthur Herbert, Arlington Heights, Mass. (Age 43, b. Cambridge, Vt.) Graduate of Worcester Polytechnic Inst., 1892. From 1893 to 1894, assistant surveyor with U. S. Lighthouse Dept.; from 1894 to 1899, designing and constructing engineer on water works, sewerage and hydraulics with Percy M. Blake; from 1899 to 1904, assistant engineer, Metropolitan Sewerage Works, on High Level Sewer and Nut Island Outfall; from 1904 to 1906, engineer with National Board of Fire Underwriters; from 1906 to date, engineer and special inspector with Factory Mutual Fire Insurance Companies. Refers to E. P. Adams, P. M. Blake, H. P. Eddy, A. D. Flinn, A. T. Safford and H. A. Symonds.

Stott, Samuel E., Boston, Mass. (Age 30, b. Lowell, Mass.) From 1902 to 1904, with B. & M. R. R. Bridge Dept., under J. P. Snow, two years in office as structural draftsman and one year in field as rodman and transitman; during 1904 and 1905, also 1909 and 1910, with H. P. Converse & Co. as structural draftsman, estimator and salesman; from 1906 to 1908 with Stone & Webster Engineering Corp. as structural draftsman; during 1910 and 1911, with Lockwood, Greene & Co. as structural and concrete designer; in April, 1911, entered employ of Swift & Co. in construction department as concrete and structural designer, and for more than a year has been chief draftsman, in charge of preparing all plans and specifications for refrigerating and rendering plants, fertilizer mills, and market and storage buildings; is associate member of American Society of Civil Engineers. Refers to A. F. Brown, E. H. Rockwell and J. P. Snow.

EMPLOYMENT BUREAU.

The Board of Government has established an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

Men Available.

158. Age 46. Has had six years' experience in the field and nine years' experience as superintendent for firm of landscape engineers; understands planting, sewer construction and drainage, and has made a specialty of road building. Desires situation with landscape designing or contracting firm.

237. Age 28. Educated in grammar school and business college. Has had thirteen years' experience with Westinghouse, Church, Kerr & Co., including three years as clerk in negotiation department, five years as private secretary, and four years as chief stenographer in full charge of stenographic department. Salary desired, $27 per week.

238. Age 24. High school education; no experience. Experience more important than salary.

239. Age 43. Educated in Boston public schools and Massachusetts Agricultural College. Experience includes five years with distribution department of Metropolitan Water Board on pipe line surveys and construction; five years in city engineer's office, Waterbury, Conn., on drafting, computation surveys and construction, mill work and installation of septic tanks; and eight years with Board of Water Supply of New York City on Hudson River Crossing of Catskill Aqueduct; was assistant to division engineer on this work for six years and in direct charge for two years, when work was completed. Prefers position near Boston, salary to be commensurate with character of work.

240. Age 29. Has had two years' experience with engineering department of Massachusetts State Board of Health on investigation of water supplies and sewage disposal works; one year on railroad surveying and concrete construction in Porto Rico, during which time he acted as chief of party and superintendent of construction; one year as estimator on general building construction; and one year as inspector of forms, reinforcement and concrete on construction of railroad viaduct. Desires position as superintendent of construction, estimator or inspector. Salary desired, $125 per month.

241. Age 44. Educated in English High and Government School of

Construction and Architecture, Chatham, England. Experience includes land surveying, drafting, quantity surveying, estimating and general superintendence on public works. Desires position as civil engineer, inspector, draftsman or estimator. Minimum salary desired, $25 per week.

244. Age 23. Graduate and post-graduate of Mechanic Arts High School; has had one year studying structures in evening school at Franklin Union. Has had five years' experience, chiefly as rodman, inspector, transitman, chief of party, and draftsman with Boston Transit Commission. Desires position as draftsman, chief of party or inspector. Minimum salary desired, $21 per week.

247. Age 27. Graduate of Royal Technical College in Copenhagen, degree of B.S. in mechanical engineering; member of Society of Danish Civil Engineers, Copenhagen. Has had two and one-half years' esperience as draftsman and designer on steel construction. Desires position as draftsman. Salary desired, $15 per week.

248. Age 33. Educated in public schools of Lowell, Boston Y. M. C. A., Cambridge Evening High School and International Correspondence School. Has had four years' experience as rodman and transitman with Old Colony St. Ry. on high tension survey from Quincy to Fall River, and seven years as transitman on subway and sewer work with Boston Elevated Ry. Co.; was chief of party on sewer construction for over a year; has also been on town survey and with U. S. Engr. Office as survey man on river survey. Desires position as draftsman or transitman. Salary desired, $90 per month.

249. Age 51. Studied in public schools of Boston and for two years at Mass. Inst. of Technology. Experience includes work on locks and canals, sewer construction and building of water works. Desires any position for which experience qualifies him.

LIST OF MEMBERS.

ADDITIONS.

Ackerman, Alexander S. .... Sandwich, Mass.
Burnes, George R. .... 8 Dartmouth St., Everett, Mass.
Burpee, George W. .... 37 Wall St., New York, N. Y.
Chapman, Benjamin R. .... City Hall, Brockton, Mass.
Ellis, Lester F. .... 36 Adams St., Winter Hill, Mass.
French, Charles A. .... Masonic Temple, Laconia, N. H.
Gray, Howard A. .... 71 Wallace St., West Somerville, Mass.
Hayward, Edwin D. .... 253 Pleasant St., Bridgewater, Mass.
Mann, Oswell F. .... 41 Marshall St., Somerville, Mass.
Mead, Royal L. .... 15 Beacon St., Boston, Mass.
Milton, Samuel L. .... 75 Massachusetts Ave., Cambridge, Mass.
Morrow, Clarence E. .... 30 Trinity Pl., Boston, Mass.
Nichols, Charles E. .... 112 Charles River Road, Cambridge, Mass.

Robinson, Ashley Q. . . . . 53 4th St., Attleboro, Mass.
Sabin, Fred D. . . . . 17 Spencer Ave., Somerville, Mass.
Storrs, Edward D. . . . . Concord, N. H.
Williams, Alexander K. . . . . 15 Park View St., Boston, Mass.
Woodbury, Stanley W. . . . . 31 Fourth Ave., Haverhill, Mass.

CHANGES OF ADDRESS.

Dean, Luther . . . . 4 Clinton St., Taunton, Mass.
Fogg, Benjamin G. . . . . Great Works, Me.
Greenough, Maurice B. . . . . 2299 Grandview Ave., Cleveland, O.
Higgins, Herman K. . . . . 209 McBride St., Jackson, Mich.
Horne, Harold W. . . . . Collinsville, Conn.
Mann, John L. . . . . 29 Broad St., Randolph, Vt.
Richardson, Lyle M. . . . . Chandler, P. Q., Canada
Sanborn, Morton F. . . . . Care State Dept. of Health, Albany, N. Y.
Shedd, Edward W. . . . . 432 Massasoit Ave., East Providence, R. I.
Thorndike, Sturgis H. . . . . 308 Boylston St., Boston, Mass.
Warren, George M.,
Drainage Investigations, Dept. of Agriculture, Washington, D. C.
Willard, Ernest C. . . . . 405 American Bank Bldg., Seattle, Wash.
Whipple, George C. . . . . Pierce Hall, Harvard Univ., Cambridge, Mass.
Whitten, Ernest P. . . . . Care Forest Service, Washington, D. C.

LIBRARY NOTES.

Recent Additions to the Library.

U. S. Government Reports.

Annual Report of Chief of Weather Bureau for 1912–13.

Annual Report of Director of Bureau of Mines for 1912–13.

Annual Report on Statistics of Express Companies for 1910–11.

Abstracts of Current Decisions on Mines and Mining, March to December, 1913. J. W. Thompson.

Action of Acid Mine Water on Insulation of Electric Conductors. H. H. Clark and L. C. Ilsley.

Alaska Coal and Its Utilization. Alfred H. Brooks.

Analyses of Coal Samples from Various Fields in United States.

Cannonball River Lignite Field, North Dakota. E. Russell Lloyd.

Coal and Lignite Fields in Montana. C. M. Bauer, G. S. Rogers and C. F. Bowen.

Contributions to Economic Geology: Part II for 1911, by Marius R. Campbell; Part I for 1912, by David White.

Darwin Silver-Lead Mining District, California. Adolph Knopf.

Drilling Wells in Oklahoma by Mud-laden Fluid Method. A. G. Heggem and J. A. Pollard.

Dust Prevention and Road Preservation Experiments, 1913.

Electric Switches for Use in Gaseous Mines. H. H. Clark and R. W. Crocker.

Flumes and Fluming. Eugene S. Bruce.

Fuel Briquetting in 1912. Edward W. Parker.

Fuel-Briquetting Investigations, 1904 to 1912. C. L. Wright.

Gases Found in Coal Mines. George A. Burrell and Frank M. Seibert.

Geology and Geography of Portion of Lincoln County, Wyoming. Alfred Reginald Schultz.

Geology of Long Island, New York. Myron L. Fuller.

Geology of Standing Rock and Cheyenne River Indian Reservations, North and South Dakota. W. R. Calvert and others.

Hydraulic Mine Filling. Charles Enzian.

Inflammable Gases in Mine Air. George A. Burrell and Frank M. Seibert.

Metal-Mine Accidents in United States during 1912. Albert H. Fay.

Mine Signboards. Edwin Higgins and Edward Steidle.

Mineral Resources of Alaska in 1912. Alfred H. Brooks and others.

Mud-laden Fluid Applied to Well Drilling. J. A. Pollard and A. G. Heggem.

Observations at Coast and Geodetic Survey Magnetic Observatory at Vieques, Porto Rico, 1911 and 1912. Daniel L. Hazard.

Observations at Coast and Geodetic Survey Magnetic

Observatory near Tucson, Arizona, 1911 and 1912. Daniel L. Hazard.

Ore Deposits in Northwestern Custer County, Idaho. Joseph B. Umpleby.

Permissible Explosives Tested prior to January 1, 1914. Clarence Hall.

Petroleums of California. Irving C. Allen and others.

Problems of Petroleum Industry. Irving C. Allen.

Production of Chromic Iron Ore in 1913. J. S. Diller.

Production of Explosives in United States during 1912. Albert H. Fay.

Production of Mica in 1913. Douglas B. Sterrett.

Production of Sand-Lime Brick in 1913. Jefferson Middleton.

Relative Effects of Carbon Monoxide on Small Animals. George A. Burrell, Frank M. Seibert and I. W. Robertson.

Reconnaissance of Granfield District, Oklahoma. Malcolm J. Munn.

Resins in Paleozoic Plants and Coals of High Rank. David White.

Results of Spirit Leveling in Illinois, 1911 to 1913, inclusive.

Results of Spirit Leveling in Oklahoma, 1895 to 1912, inclusive.

Results of Triangulation and Primary Traverse, 1911 and 1912. R. B. Marshall, author also of two reports preceding.

(The) Road Drag and How it is Used. July, 1914.

Safety and Efficiency in Mine Tunneling. David W. Brunton and John A. Davis.

Sampling and Examination of Mine Gases and Natural Gas. George A. Burrell and Frank M. Seibert.

San Franciscan Volcanic Field: Arizona. Henry Hollister Robinson.

Some Cerusite Deposits in Custer County, Colorado. J. Fred. Hunter.

Sulphur, Pyrite and Sulphuric Acid in 1912. W. C. Phalen.

Tests of Permissible Explosives. Clarence Hall and Spencer P. Howell.

Upper Cretaceous and Eocene Floras of South Carolina and Georgia. Edward Wilber Berry.

Uranium, Radium and Vanadium. Richard B. Moore and Karl L. Kithil.

Uses for Chestnut Timber Killed by Bark Disease. J. C. Nellis.

Utilization of Petroleum annd Natural Gas in Wyoming. W. R. Calvert.

Water-Supply Papers Nos. 304, 309, 322, 324, 333, 337, 340-A, 345-B, C, D and E.

Weathering of Pittsburgh Coal Bed at Experimental Mine near Bruceton, Penn. Horace C. Porter and A. C. Fieldner.

State Reports.

Massachusetts. Annual Report of Gas aand Electric Light Commissioners for 1913.

Massachusetts. Annual Report of Metropolitan Park Commissioners for 1913.

Massachusetts. Annual Report of Metropolitan Water and Sewerage Board for 1913.

Massachusetts. Fertilizing Value of Sewage and Sewage Sludge. H. W. Clark.

New York. Annual Report of Public Service Commission for First District for 1912, Vol. II.

Ohio. Annual Report of State Board of Health for 1912.

City and Town Reports.

Beverly, Mass. Annual Report of Water Board for 1914.

Brockton, Mass. Annual Report of City Engineer for 1913.

Chicago, Ill. Report of City Waste Commission for 1914.

Chicago, Ill. Second Plea for Publicity in Office of County Treasurer. Bureau of Public Efficiency.

Cincinnati, O. Progress Report on Plan of Sewerage, 1912–13.

Erie, Penn. Annual Report of Commissioners of Water Works for 1913.

Fitchburg, Mass. Semi-Annual Reports of Sewage Disposal Commission for 1913.

Gloucester, Mass. Annual Report of Water Commissioners for 1913.

Haverhill, Mass. Annual Report of City Engineer for 1913.

Holyoke, Mass. Annual Report of Water Commissioners for 1913.

Madison, Wis. Annual Report of Water Commissioners for 1913.

New Orleans, La. Semi-Annual Report of Sewerage and Water Board, December, 1913.

New York, N. Y. Annual Report of Board of Water Supply for 1913.

New York, N. Y. Report of Metropolitan Sewerage Commission on Main Drainage and Sewage Disposal Works Proposed for New York City, 1914.

New York, N. Y. Supplementary Report on Disposal of New York's Sewage, June 30, 1914.

St. Louis, Mo. Annual Report of Water Commissioner for 1914.

Salem, Mass. Annual Report of Director of Public Works for 1913.

Somerville, Mass. Annual Reports for 1913.

Worcester, Mass. Annual Report of Water Commissioner for 1913.

Miscellaneous.

Abenaque Machine Works. Portable Air Compressors.

American Wood Preservers' Ass'n: Quantity of Wood Preservatives Consumed and Amount of Wood Treated in U. S. in 1913. Clark W. Gould.

Artistic Bridge Design. Henry Grattan Tyrrell.

Catskill Water Supply of New York City. Lazarus White.

Civil Engineer's Pocket Book. A. I. Frye.

Check List of Bibliographies Relating to Municipal Government. Joseph Wright.

Chicago City Club: Through Routes for Chicago's Steam Railroads. George Ellsworth Hooker.

Croton Water Supply: Its Quality and Purification. George W. Fuller.

Design of Plate Girders. L. E. Moore.

First American Fire Prevention Convention. Official Record. Powell Evans, Ed.

Foundations of Bridges and Buildings. H. S. Jacoby and R. P. Davis.

National Conference on Concrete Road Building, February, 1914. Proceedings.

National Fire Protection Association: Salem Conflagration.

Railway Library and Statistics for 1913. Slason Thompson, Ed.

Stone & Webster Engineering Corporation: Steam Power Stations.

Text-Book on Highway Engineering, 1913 ed. Arthur H. Blanchard and Henry B. Drowne.

Vibration Produced by Working of Traffic on Central London Railway. A. Mallock.

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before the 25th of each month.)

Commonwealth of Massachusetts. — METROPOLITAN PARK COMMISSION. — The following work is in progress:

Woburn Parkway. — Pleasant Street, Woburn, to Pond Street, Winchester.

Charles River Reservation. — Dredging river from North Beacon Street to Watertown.

Middlesex Fells Parkway. — West Border Road, Malden.

Nahant Beach Parkway. — Filling inside bulkhead in Lynn Harbor with material dredged from Lynn Harbor.

Revere Beach Reservation. Building about 1 500 linear feet of shore protection with reinforced concrete.

Plans have been prepared and proposals received for work of reconstructing the northerly portion of Wellington Bridge, destroyed by fire of June 5.

City of Boston. — PUBLIC WORKS DEPARTMENT, HIGHWAY DIVISION, PAVING SERVICE. — Work is in progress on the following streets:

Old Colony Ave.,	Hyde St. to Mt. Vernon St.	Bituminous macadam.
Brookdale St.,	Florence St. to Sycamore St.	Tar macadam.
Metropolitan Ave.,	Kittredge St. to Granada Ave.	Artificial stone sidewalk.
Manthorne Rd.,	Centre St. to Weld St.	Bituminous macadam.
St. Rose St.,	600 ft. south and west of Jamaica St. Arborway.	Tar macadam.
Denton Terrace,	Washington St. to Kittredge St.	Tar macadam.
Wellington Hill St.,	Blue Hill Ave. to Morton St.	Asphalt macadam.
Seaver St.,	Humboldt Ave. to Walnut Ave.	Excavate and grade.
Massachusetts Ave.,	R. R. Bridge to Columbia Rd.	Pave and regulate.
Zeigler St.,	Warren St. to Dearborn St.	Bithulithic.
Eustis St.,	Dearborn St. to Magazine St.	Bithulithic.
Shirley St.,	Norfolk St. to 500 ft. northerly.	Pave and regulate.
Atkinson St.,	Southampton St. to South Bay Ave.	Hassam Block pavement.
Avery St.,	Tremont St. to Washington St.	Bithulithic.
Dillaway St.,	Hollis St. to Dix Pl.	Bithulithic.

New York, New Haven & Hartford Railroad. — Clinton Mass. Elimination of Grade Crossings. — Work on the B. & M. R. R. now in progress is the erection of a passenger station, the development of the transfer yard between the two railroads and track work incidental to the permanent location of the main lines throughout the limits of the work.

Work on the N. Y., N. H. & H. R. R. is the grading for the permanent embankment, track work, building platforms for the new station and general clearing up of the location.

Aberthaw Construction Company. — Boston, Mass. — *South Boston, Fish Pier.* The outside walls of the Cold Storage Building are completed and about one half the concrete floors are in place. The ice-making plant is completed and running. This group of buildings has been built with steel molds for the outside walls. At the present time the Cold Storage Building is being lined throughout with cork insulation, the floors laid with four inches of cork mopped down with asphalt and covered with concrete paving and the walls lined with six inches of cork in three layers. The type of building used here is new to these parts, being steel, covered with concrete for walls and floors.

South Framingham, Mass. The Aberthaw Construction Company is building the new reinforced concrete printing build-

ing for the Dennison Manufacturing Company. The foundations are in and the first floor work is just starting. Monks & Johnson are the engineers.

The Fore River Shipbuilding Co., Quincy, Mass., has the following work in progress:

U. S. Battleship *Nevada.*

U. S. Submarine Tender *Fulton.*

Eight U. S. submarine boats.

U. S. Torpedo Boat Destroyers *Cushing* and *Tucker.*

Freight Steamer *Pacific.*

Turners Falls Company, Turners Falls, Mass. — This company is combining a partially developed fall of 40 ft. with a undeveloped fall of 18 ft. by enlarging and extending its present canal from Turners Falls to Montague City. The new canal of approximately 3 000 sq. ft. of section, an artificial pond of 40 acres to be created for regulation purposes, and its extension to a site on the Connecticut River about opposite the Montague City Station of the Boston & Maine Railroad, with the hydro-electric power station and equipment, comprise the bulk of the new work. The total length of canal when complete will be about 11 000 ft.

This year's work consists of a large amount of rock excavation above and under water in the present canal; and contracts 20 and 21, aggregating in cost about $1 200 000.

Contract 20 is for digging the extension to the present canal through rock, sand and gravel, building the embankments to form the pond, and excavating the canal from the pond to the site of the power house. This contract includes nearly a million yards of excavation, about one half of this to be placed in embankments, special work of cut-offs, changes in sewers and railroads, wasteways for ice and sluice-ways for drawing off the water.

Contract 21 includes the foundations for a power house 261 ft. long by 100 ft. wide, to contain ultimately six 9 700 horse-power vertical scroll-case wheels, driving the same number of 6 000 kw. umbrella-type generators under 54 ft. net head. Three

of these water wheel units have been contracted for with the I. P. Morris Co. of Philadelphia, Pa., and the same number of generators with the General Electric Company of Schenectady, N. Y., for delivery next summer. Contracts for the power station structure will probably be let this fall.

The Turners Falls Company has been working upon this development for the past four years, having in 1912 widened their original canal from 50 ft. to 125 ft.; completed the Turners Falls half of a new concrete dam, sluice gates and new head gates in 1912–1913; and taken down and dredged the filling from a portion of their old dam this year.

This particular development will be interesting to New England engineers on account of its size (a maximum of 36 000 kw. requiring about 10 000 cu. ft. per second), the length of canal with artificial pond for regulating purposes, and the type and size of the generating units.

The work on the canal and Contract 20 is being done by Holbrook, Cabot & Rollins, of Boston; the power-house foundations and generator foundations by F. T. Ley & Co., of Springfield, Mass., under the direction of Howard M. Turner, hydraulic engineer for the Turners Falls Company, with H. A. Moody in charge of Contract 21. The consulting engineers for the work are Arthur T. Safford on general hydraulic questions and Frederick P. Stearns, of Boston, on embankments and cut-offs.

The company will continue to supply power to its permanent lessees in Turners Falls, but develop the additional power for general purposes in the neighborhood and the Connecticut Valley as far down as Springfield, Mass.

Vol. I OCTOBER, 1914 No. 8

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

PROCEEDINGS

PAPERS IN THIS NUMBER.

"Sewage Measurement and Automatic Control of Storm Overflow at Pawtucket, R. I." George A. Carpenter.

(Presented before the Sanitary Section, February 4, 1914.)

"The Venturi Meter for Sewage Measurement." Charles G. Richardson.

(Presented before the Sanitary Section, February 4, 1914.)

"Descriptions of Devices for Measuring the Flow of Sewage." Edw. Wright, Jr., F. A. Marston, F. B. Sanborn, E. H. Rogers and E. J. Fort.

(Presented before the Sanitary Section, February 4, 1914.)

Discussion of "Cost Accounting on Construction Work," with Author's Closure.

CURRENT DISCUSSIONS.

Paper.	Author.	Published.	Discussion Closes.
"Run-off from Sewered Areas."	Committee.	June.	Oct. 15.
"The Mechanics of Reinforced Concrete."	C. A. P. Turner.	Sept.	Nov. 10.

REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on Wednesday, October 21, 1914, at 7.45 o'clock P.M., in

CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. William D. Sohier, Chairman of the Massachusetts Highway Commission, will present a paper on "French, English and American Roads and Road Systems," illustrated by lantern slides.

MINUTES OF MEETINGS.

BOSTON, September 16, 1914. — A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order at 7.45 o'clock by the President, Mr. Harrison P. Eddy. There were present 121 members and visitors.

The record of the June meeting was read and approved.

The Secretary reported for the Board of Government that it had elected to membership in the grade of member the following: Charles Richard Berry, George Leonard Hosmer, John Wardwell Howard, Edward Percy Lane, Leo Solomon Stone and Harrison Parker Wires.

Mr. Blake, for the Committee on Social Activities, announced that in connection with the next meeting of the Society, the committee was making arrangements for what they expected would be even a more enjoyable occasion than that preceding the June meeting.

The President then introduced Mr. E. S. Martin, of New York, who, in the absence of the author, Mr. C. A. P. Turner, of Minneapolis, read the paper of the evening, entitled "The Mechanics of Reinforced Concrete under Flexure in Beam and Slab Types."

The paper was discussed in a brief written communication from Mr. J. R. Worcester, which was read by the Secretary, and by Messrs. L. J. Johnson, S. E. Thompson and H. F. Bryant,

of the Society, and by Mr. J. R. Nichols, of Boston, and Mr. Martin.

On motion of Professor Johnson, the thanks of the Society were voted unanimously to Mr. Martin for his courtesy in attending the meeting and presenting the paper.

Adjourned.

S. E. TINKHAM, *Secretary.*

APPLICATIONS FOR MEMBERSHIP.

[September 28, 1914.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse candidate.

BESSEY, ROY FREDERIC, Corozal, Canal Zone. (Age 26, b. Brooklyn, N. Y.) Graduate of high school, January, 1906; obtained technical education in evening school in New York and at Association Inst., Boston. From 1906 to 1911, with New York Central & Hudson River R. R., first as clerk and later as rodman in engineering department; from 1909 to 1911, with Boston & Albany R. R. as rodman on Worcester improvement; from June, 1911, to date, with Isthmian Canal Commission as draftsman on design of reinforced concrete, timber and steel structures. Elected a junior October 19, 1910, and now desires to be transferred to grade of member. Refers to R. D. Bradbury, C. B. Breed, H. B. Luther and L. G. Morphy.

HAMMOND, NEWTON LEROY, Newton, Mass. (Age 28, b. Newport, R. I.) Took four years course in civil engineering at Mass. Inst. of Tech-

nology, 1904-08. During summers of 1904 and 1905, rodman and transitman with schoolhouse department, city of Boston; during summers of 1906 and 1907, assistant engineer with New England Gas & Coke Co. and Boston Cons. Gas Co. on construction of water gas plant at Everett, Mass.; 1908, manager of traffic department for W. H. McElwain Shoe Co., Boston; spring of 1909, assistant engineer with F. W. Bird & Son, East Walpole, Mass.; summer of 1909, inspector of sewers, Brookline, Mass.; from September, 1909, to November, 1911, assistant engineer on construction of dam for water supply, New Britain, Conn.; from November, 1911, to present time, principal assistant engineer on Neponset River Improvement with state department of health. Refers to E. M. Blake, P. M. Blake, A. H. French, X. H. Goodnough and David Reynolds.

WALDSTEIN, JULIUS, Bristol, R. I. (Age 29, b. Kovno, Russia.) Graduate of Mass. Inst. of Technology, 1911, in civil engineering course. From September 1, 1911, to March, 1912, rodman with Pere Marquette R. R., Benton Harbor, Mich.; from June, 1912, to September, 1913, computer and draftsman with Union Development Co., Bryson City, N. C.; is now engineer with L. H. Callan, contractor, Bristol, R. I. Refers to C. F. Allen, C. B. Breed, L. E. Moore and C. M. Spofford.

EMPLOYMENT BUREAU.

THE Board of Government has established an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

MEN AVAILABLE.

236. Age 23. Graduate of Mass. Inst. of Technology, 1913. Has worked summers during college course as rodman with Boston Elevated Railway Co. and with Power Construction Co., Hoosac Tunnel, Mass., also as rodman and instrumentman with Directors of Port of Boston; during August and September, 1913, was instructor at Technology Surveying Camp; from October, 1913, to June, 1914, assistant in civil engineering, Mass. Inst. of Technology. Desires position as instrumentman. Salary desired, $75 per month.

250. Age 27. Graduate of Stoneham High School, 1905, and of Mass. Inst. of Technology, 1914. Experience includes two years as mechanical draftsman with Shawmut Motor Co., Stoneham, and five months in same capacity with Blake & Knowles Pump Works, E. Cambridge; seven months as structural draftsman with B. & M. R. R. engineering department, and one year as rodman and transitman with same company. Prefers position as transitman, but will accept any position in engineering work that offers good experience and chance for advancement. Salary desired, not less than $15 per week.

251. Age 35. Graduate of Lehigh University, civil engineering course, 1899. Has had fifteen years' experience, chiefly in concrete construction — heavy foundations, cofferdams, concrete piling — and in railroad construction and maintenance. Desires position as outside man for engineer or contractor, to handle either engineers' field work or inspection, or as contractor's superintendent. Salary desired, $150 per month.

252. Age 30. Graduate of Mass. Inst. of Technology and Associate Member of American Society of Civil Engineers. Has had considerable experience as mining and hydraulic engineer and in construction of various kinds, including city sewer construction, machine tunneling and erection of hydro-electric power plant. Desires position as contractor's superintendent, foreman, or with consulting engineer. Salary of minor importance.

253. Age 24. Graduate of Mass. Inst. of Technology, 1913, civil engineering course. Has had about six months' experience both in office and field with firm of civil and consulting engineers. Desires position in civil engineering lines. Experience of more importance than salary.

204. Age 25. Good technical education. Has had six years' experience in both field and office engineering work on railroad and canal construction, with New York Central and Boston & Albany railroads (including Worcester Improvement), and with Panama Canal; for past three years has been draftsman on design of concrete, reinforced concrete, steel and timber structures. Desires to return to United States. Salary desired, $125 per month.

255. Age 25. Graduate of Tufts College, 1908, degree of B.S. in electrical engineering. Experience includes work in power department of Boston Elevated Ry. Co., as draftsman with Bay State St. Ry. Co. and Stone & Webster Engrg. Corp'n, and as engineer with Tennessee Exploration Co., Knoxville, Tenn. Desires position as draftsman or engineer. Salary desired, $100 per month.

256. Age 24. Graduate of Mass. Inst. of Technology, 1914, civil engineering course. During summer of 1912 was timekeeper on concrete construction; during summer of 1913, concrete draftsman; at present, concrete draftsman. Desires position as concrete inspector or draftsman. Salary desired, $18 per week.

LIST OF MEMBERS.

ADDITIONS.

Hosmer, George L. . . . . 350 Salem St., Woburn, Mass.
Howard, John W. . . . . Mass. Inst. of Technology, Boston, Mass.

CHANGES OF ADDRESS.

Albee, Edward E. 11 Norwood St., Manchester, Mass.
Carty, John E. . . . . 602 City Hall Annex, Boston, Mass.
Dotten, William J. care Draper Co., Hopedale, Mass.
Fay, Frederic H. . . . . 308 Boylston St., Boston, Mass.
Ford, Walter A. . . . . 31 Harlem St., Dorchester, Mass.
Hammond, Wilberforce B. . . . . 19 Everett St., Cambridge, Mass.
Jerome, F. Jay . . . . 113 Park Place, Painesville, Ohio.
Langley, Miles E. . . . . 4 College St., Brunswick, Me.
Macksey, Henry V. . . . . . . 16 Board of Trade Bldg., Calgary, Alberta, Can.
McFarlin, C. Kirk . . . . 170 Glenwood Ave., East Orange, N. J.
Morrison, Harry J. . . . . 50 McClellan Ave., Amsterdam, N. Y.
Peirce, Frank A. . . . . Box 844, Columbus, Ga.
Rice, Arthur P. . . . . P. O. Box 86, Sterling, Mass.
Richardson, Thomas F. . . . . 346 Montross Ave., Rutherford, N. J.
Shaw, Arthur L. . . . . 383 Madison St., Fall River, Mass.
Skinner, Fenwick F. . . . . 315 W. 20th St., New York, N. Y.
Snow, Walter B. . . . . 136 Federal St., Boston, Mass.
Turner, Daniel L. . . . . 606West 116th St., New York, N. Y.
Umstead, Charles H. . . . . Clarksville, Tex.
Wentworth, John P. Box 62, Northeast Harbor, Me.

LIBRARY NOTES.

Recent Additions to the Library.

U. S. Government Reports.

Annual Report of Chief Engineer of War Department for 1913.

Cement Industry in United States in 1913. Ernest F. Burchard.

Central Electric Light and Power Stations and Street and Electric Railways, 1912.

Coal Fields in Idaho, Washington and Oregon. E. G. Woodruff and C. E. Lesher.

Combustion of Coal in Boiler Furnaces. J. K. Clement, J. C. W. Frazer and C. E. Augustine.

Composition of Crinoid Skeletons. F. W. Clarke and W. C. Wheeler.

Construction of Dams across Navigable Waters: Letter from Brig.-General Bixby.

Cotton Production, 1913.

Yields from Destructive Distillation of Certain Hardwoods.

Dike Rocks of Apishapa Quadrangle, Colorado. Whitman Cross.

Electric Activity in Ore Deposits. Roger C. Wells.

Experiments with Furnaces for Hand-fired Return Tubular Boiler. Samuel B. Flagg, George C. Cook and Forrest E. Woodman.

Production of Feldspar in 1913. Frank J. Katz.

Financial Statistics of Cities having a Population of over 30 000: 1912 and 1913 (2 issues).

Production of Fuller's Earth in 1913. Jefferson Middleton.

Production of Graphite in 1913. Edson S. Bastian.

Production of Manganese and Manganiferous Ores in 1913. D. F. Hewett.

Middle Triassic Marine Invertebrate Faunas of North America. James Perrin Smith.

Production of Mineral Paints in 1913. James M. Hill.

Oil and Gas Fields in Wayne and McCreary Counties, Kentucky. M. J. Munn.

Oil and Gas in Western Part of Olympic Peninsula, Washington. Charles T. Lupton.

Oil Shale of Northwestern Colorado and Northeastern Utah. E. G. Woodruff and David T. Day.

Ore Deposits of Northeastern Washington. Howland Bancroft.

Production of Phosphate Rock in 1913. W. C. Phalen.

Potash Salts: Summary for 1913. W. C. Phalen.

Recovery of Secondary Metals in 1913. J. P. Dunlop.

Production of Silica in 1913. Frank J. Katz.

Production of Slate in 1913. A. T. Coons.

Spirit Leveling in Kansas, 1896 to 1913, inclusive.

Spirit Leveling in Oregon, 1896 to 1913, inclusive.

Spirit Leveling in State of Washington, 1896 to 1913, inclusive. Last three items by R. B. Marshall.

Production of Talc and Soapstone in 1913. J. S. Diller.

Telephones and Telegraphs, 1912.

Tyloses: Their Occurrence and Practical Significance in Some American Woods. Eloise Gerry.

Useful Minerals of the United States. Samuel Sanford and Ralph W. Stone.

Water Supply Papers 306, 323, 340-B, 580-D and E.

State Reports.

Massachusetts. Annual Report of Highway Commission for 1913.

Massachusetts. Annual Report of Public Service Commission for 1913, Vol. I.

Massachusetts. Railroad, Railway and Telephone Laws, 1914.

New Jersey. Annual Report of State Board of Health for 1913.

New York. Annual Report of State Engineer and Surveyor for 1913, Vol. I.

City and Town Reports.

Albany, N. Y. Annual Report of Bureau of Water for 1913.

Kansas City, Mo. Annual Report of Fire and Water Commissioners for 1913.

Lynn, Mass. Annual Report of Commissioner of Water Works for 1913.

Medford, Mass. Annual Report of City Engineer for 1913.

Newton, Mass. Annual Report of City Engineer for 1913.

Plainfield, N. J. Annual Report of City Officers for 1913.

Salt Lake City, Utah. Annual Reports of City Officers for 1913.

Springfield, Mass. Annual Report of Water Commissioners for 1913.

Waltham, Mass. Annual Reports of City Engineer, Superintendent of Sewers and Board of Survey for 1913.

Westerly, R. I. Annual Reports of Water Commissioners for 1897, 1898, 1900 to 1912.

Worcester, Mass. Annual Report of Water Commissioner for 1913.

Miscellaneous.

American Society for Testing Materials: Proceedings for 1902 and 1904 to 1912, inclusive; Year-Books for 1910 and 1911. Gift of L. C. Wason.

International Association for Testing Materials: Proceedings, 1909 and 1912. Gift of L. C. Wason.

Mass. Inst. of Technology. Contributions from Sanitary Research Laboratory, Vols. III and V. Gift of C. W. Sherman.

Municipal Engineers of City of New York. Assessments for Local Improvements. William C. Ormond.

National Board of Fire Underwriters: Reports on the following cities: Altoona, Pa.; Amsterdam, N. Y.; Asbury Park, N. J.; Atlanta, Ga.; Atlantic City, N. J.; Bayonne, N. J.; Bridgeport, Conn.; Charleston, W. Va.; Chelsea, Mass.; Chester, Pa.; Chicago, Ill.; Cleveland, Ohio; Dayton, Ohio; East Orange, N. J.; Evansville, Ind.; Fort Smith, Ark.; Galveston, Tex.; Glens Falls, N. Y.; Harrisburg, Pa.; Hoboken, N. J.; Hot Springs, Ark.; Jackson, Miss.; Johnstown, Pa.; Little Rock, Ark.; Lowell, Mass.; Memphis, Tenn.; Meridian, Miss.; Montgomery, Ala.; Newark, N. J.; New Haven, Conn.; North Adams, Mass.; Norwich, Conn.; Ogdensburg, N. Y.; Orange, N. J.; Passaic, N. J.; Paterson, N. J.; Perth Amboy, N. J.; Philadelphia, Pa.; Pine Bluff, Ark.; Plainfield, N. J.; Providence, R. I.; Reading, Pa.; Richmond, Va.; Rochester, N. Y.; Scranton, Pa.; Springfield, Mass.; Syracuse, N. Y.; Texarkana, Ark.-Tex.; Trenton, N. J.; Troy, N. Y.; Union, N. J.; Utica, N. Y.; West Hoboken, N. J.; Wheeling, W. Va.; Williamsport, Pa.; Wilmington, Del.; Worcester, Mass.; Youngstown, Ohio; Special Report on Panama-Pacific Exposition.

Members will please note that we have received two more volumes of the reports of the Sanitary Research Laboratory of the Massachusetts Institute of Technology. We still lack volumes I and II. Cannot some member supply us with these volumes?

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary 715 Tremont Temple, Boston, before the 25th of each month.)

United States Government. — NAVY DEPARTMENT. — *Navy Yard, Boston.* — Plans for building ways for supply ship are completed and the work is advertised.

Commonwealth of Massachusetts. — METROPOLITAN WATER AND SEWERAGE BOARD. — *Water Works.* — About 70 per cent. of the excavation and brick lining for the water-pipe tunnel under Chelsea Creek, between East Boston and Chelsea, which is being constructed by the pneumatic process, is now completed. The work is progressing at the rate of about 50 linear feet of tunnel per week.

The concrete foundation for the reservoir which is being constructed on the summit of Bellevue Hill in West Roxbury is nearly completed.

The steel tank which is to be erected on this foundation will be 100 ft. in diameter and 44 ft. high and will have a capacity of 2 500 000 gal. The shop work on the tank is well advanced and the plant for its erection is now being installed on Bellevue Hill.

Work is in progress on the Southern High Service 24-in. pipe line in Adams St. in Milton, and on the Southern Extra High Service 20-in. pipe line in Beech St., West Roxbury.

METROPOLITAN PARK COMMISSION. — The following work is in progress:

Charles River Reservation. — Dredging river from North Beacon St. to Watertown.

Middlesex Fells Parkway. — Reconstruction of burned portion of Wellington Bridge.

Revere Beach Reservation. — Construction of reinforced concrete shore protection.

Winthrop Shore Reservation. — Bids have been received for

the construction of about 1 500 ft. of sea wall at northerly end of reservation. Work will be started immediately.

METROPOLITAN WATER AND SEWERAGE BOARD. — *Sewerage Work.* — Work in Section 69, new Mystic Sewer, at Winchester, is in progress; the relief outfall sewer at Nut Island, consisting of 1 400 ft. of 60-in. cast-iron pipe, will be begun shortly, and bids have recently been received for a new screen house at the East Boston Pumping Station.

STATE DEPARTMENT OF HEALTH. — *Neponset River Improvement.* — The work of improving the Neponset River is very nearly 90 per cent. completed. The new channel has been practically finished from the railroad bridge below Fairmount Ave. in Hyde Park up to the highway bridge crossing the river on Neponset St. below Canton Junction, a total distance of about 8 miles, with the exception of a short length in the Hyde Park district below Glenwood Ave. At the latter point, ledge rock was encountered over a length of about 150 ft. which will soon be brought down to grade. There remains to be completed the short section from the dam at the Mattapan Paper Mills up to the railroad bridge below Fairmount Ave. in Hyde Park and the section above Neponset St. in Norwood and Canton. It is expected that all of the dredging at present provided for will be finished early in 1915.

A 10-in. cast-iron water main has been removed at Glenwood Ave. in Hyde Park and replaced with a 12-in. pipe, and the cast-iron sewer crossing at Dana Ave. has been protected by a concrete covering. The towns of Canton and Westwood have replaced the highway bridges on Green Lodge St. and Dedham Road with substantial new timber structures. The towns of Norwood and Canton and the County Commissioners of Norfolk County are planning to replace the bridge on Neponset St. with a new reinforced concrete structure. The contractor has three crews at work filling in the meadow cut-offs, opening up drainage channels through the spoil banks and excavating a new outlet channel for Purgatory Brook. Besides the dipper and orange-peel bucket dredges, there is also a small suction dredge in operation near Dedham Road.

Directors of the Port of Boston. — *Viaduct.* — The 1 180-ft. viaduct from Summer St. to the second floor of Commonwealth Pier 5, together with the ramp, about 500 ft. long, from the viaduct to D St., were opened to traffic on September 14.

Heating Plant. — The heating plant is practically finished and has been under operating conditions for two or three weeks.

Dry Dock. — About 9 500 lin. ft. of bulkhead out of 10 300 ft. is practically completed. Dredging from the Reserved Channel is in progress by the suction dredge "Tampa," and the material is being pumped through a 20-in. pipe line about 2 000 ft. long, and deposited within the north bulkhead at the rate of about 100 000 cu. yd. per month. The dredging of the inner end of the Reserved Channel is about one third compelted.

Pier No. 5. — The pier is practically completed, with the exception of a few odd items and the finishing coat of paint which is now being applied. A contract has been awarded for the construction of cargo hoists.

Pier No. 6 (Fish Pier). — The work of paving the inner end of the pier was resumed last week.

Railroad Freight Yard at South Boston. — This construction work has been completed.

Pier 1, East Boston. — Dredging in connection with the construction of Pier No. 1 is about three quarters finished, the docks having been completed, but considerable remains to be done outside.

Dorchester Bay. — Two dredges are at work in Dorchester Bay, enlarging and deepening the channel near Commercial Point. To date about 25 000 cu. yd. of material have been taken out.

Weymouth Fore River. — A contract has been awarded to the Eastern Dredging Co. for dredging a channel in Weymouth Fore River just above Quincy Point Bridge.

City of Boston. — Public Works Department, Highway Division, Paving Service. — Work is in progress on the following streets:

Riverview Rd.,	Brooks St. to Ranelegh Rd.,	Bituminous macadam.
Manthorne Rd.,	Centre St. to Weld St.,	Bituminous macadam.

St. Rose St.,	600 ft. south and west of Jamaica St. to Arborway.	Bituminous macadam.
Denton Terrace,	Washington St. to Kittredge St.	Bituminous macadam.
Kittredge St.,	Metropolitan Ave. to Cornell St.	Bituminous macadam.
Pinehurst St.,	Belgrade Ave. to Dudley Ave.	Bituminous macadam.
Anawan Ave.,	Oriole St. to Park St.	Artificial stone sidewalk.
Seaver St.,	Walnut St. to Humboldt Ave.	Excavating and grading.
Trescott St.,	Pleasant St. to Bakersfield St.	Bitulithic.
Massachusetts Ave.,	R. R. Bridge to Columbia Rd.	Paving and regulating.
Atkinson St.,	Southampton St. to South Bay Ave.	Paving and regulating.
Avery St.,	Tremont St. to Washington St.	Bithulithic.
Clarendon St.,	Columbus Ave. to Tremont St.	Bitulithic.

PUBLIC WORKS DEPARTMENT, SEWER AND WATER DIVISION. — *Sewer Service.* — The following work is in progress:

Substructure of Union Park St. Pumping Station on South End Improvement Project is nearly ready for the superstructure and placing of pumping machinery.

The Davenport Brook Conduit, a large reinforced concrete surface drain. Large double structure now under construction between Adams and Hallet Sts., single structure between Wessex and Codman Sts.

New York, New Haven & Hartford Railroad. — CLINTON MASS. — *Elimination of Grade Crossings.* — Work on the B. & M. R. R. now in progress is the erection of a passenger station, track work incidental to the permanent location of the main lines throughout the limits of the work, grading slopes and clearing up.

Work on the N. Y., N. H. & H. R. R. is the building of sidewalk shelters under the various bridges, the erection of permanent fences for the platforms, the building of a retaining wall for the new connection to the sidetrack for the Clinton Wire Cloth Company and the grading of the finished slopes.

The Fore River Shipbuilding Co., Quincy, Mass., has the following work in progress:

U. S. Battleship *Nevada.*

U. S. Submarine Tender *Fulton.*

Eight U. S. submarine boats.

U. S. Torpedo Boat Destroyers *Cushing* and *No. 57.*

Vol. I NOVEMBER, 1914 No. 9

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

NOTICE OF REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on

WEDNESDAY, NOVEMBER 18, 1914,

at 7.45 o'clock P.M., in CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. Henry M. Waite, city manager of Dayton, Ohio, will address the Society on "The Commission-Manager Form of Government and Its Relation to the Engineering Profession."

PAPERS IN THIS NUMBER.

"The Boston & Albany Railroad Improvements at Worcester, Mass." Luis G. Morphy.

(Presented February 18, 1914.)

Discussion of "The Mechanics of Reinforced Concrete." E. S. Martin, J. R. Worcester, L. J. Johnson, S. E. Thompson and H. F. Bryant.

Current Discussions.

Paper.	Author.	Published.	Discussion Closes.
"The Mechanics of Reinforced Concrete.	C. A. P. Turner.	Sept.	Dec. 10.
"Sewage Measurement at Pawtucket."	G. A. Carpenter.	Oct.	Dec. 10.
"The Venturi Meter."	C.A.Richardson.	Oct.	Dec. 10.
"Devices for Measuring Sewage."	E. Wright, Jr., F. A. Marston, J. W. Bugbee, E. H. Rogers, E. J. Fort.	Oct.	Dec. 10.

Erratum.

A mistake in the copy received by the Editor caused the name of Frank B. Sanborn to be printed in place of that of Julius W. Bugbee, on page 447 of the October Journal, as the author of the description of the device for measuring the flow of sewage at Providence. Both Mr. Bugbee and Professor Sanborn took part in the discussion of the subject at the February meeting of the Sanitary Section, but the material presented by Professor Sanborn appeared in the Report of the Committee on Run-off from Sewered Areas, which was published in June.

MINUTES OF MEETING.

Boston, October 21, 1914. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order at 8 o'clock by the President, Mr. Harrison P. Eddy. There were present 181 members and visitors, including ladies.

By vote the reading of the record of the last meeting was dispensed with, and it was approved as printed in the October JOURNAL.

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Members: Carl Stephens Ell, Arthur Willard French, Timothy Richard Lyons, John Bruce Mailey, Dana Newton Peaslee, Harold Long Robinson, Ralph Earle Runels, Arthur Herbert Smith and Samuel E. Stott.

Associate: George Clifford Ambrose.

Juniors: Gaetano Maconi and George Summers Sawyer.

The President then introduced Col. William D. Sohier, chairman of the Massachusetts Highway Commission, who addressed the Society on "French, English and American Roads and Road Systems." The lecture was very fully illustrated with lantern slides made from photographs taken by Colonel Sohier on his various trips through France, England and this country.

After passing a vote of thanks to Colonel Sohier for his interesting address, the Society adjourned.

S. E. TINKHAM, *Secretary*.

APPLICATION FOR MEMBERSHIP.

[November 2, 1914.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

SEARS, WALTON HARVEY, Arlington, Mass. (Age 33, b. Newton Center, Mass.) Graduate of Mass. Inst. of Technology, 1902, in mechanical engineering course. From June to December, 1902, with Pennsylvania Steel Co.; from December, 1902, to August, 1904, with B. & M. R. R. as draftsman in motive-power department; from August, 1904, to August, 1910, with Charles River Basin Commission, first as mechanical engineer and later as division engineer in charge of office; from August, 1910, to date, assistant engineer with Lockwood, Greene & Co., Boston. Is Associate Member American Society of Civil Engineers. Refers to H. S. Adams, F. W. Hodgdon, J. L. Howard, H. A. Miller, F. E. Shedd and E. C. Sherman.

EMPLOYMENT BUREAU.

THE Board of Government maintains an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

MEN AVAILABLE.

257. Age 34. Graduate of University of Vermont, 1906, civil engineering course. Has worked as assistant to superintendent on electric railway construction, Lowell and Ayer lines; has had six and one-half years' experience as division and assistant engineer with U. S. R. S., Washington, and six months' experience as office engineer with Southern Alberta Land Co. Up to April 1, 1915, will accept any position that pays $100 per month.

258. Age 30. Graduate of Sheffield Scientific School, Yale University, civil engineering course. Has had eight and one-half years' experience in construction department of N. Y., N. H. & H. R. R., chiefly on electrification projects, including four years as resident engineer and, later, as principal assistant engineer in electrification department, and two and one-half years as

resident engineer engaged in preparation of plans and estimates for increased traffic facilities from Boston to Providence. Desires position as contractor's engineer or superintendent or as engineer or assistant engineer on construction work of any description.

259. Age 22. Graduate of Tufts College, 1914, with degree of B.S. in structural engineering. Has had brief experience in detailing reinforced concrete. Desires position as draftsman or inspector. Salary desired, $65 per month.

260. Age 26. Graduate of Dartmouth College, 1912, and of Thayer School of Civil Engineering, 1913. Experience includes work on surveying and laying out of city lots, grades for streets, etc.; also inspecting and testing of cement and concrete, and detailing, estimating and some designing of steel for reinforced concrete buildings. Would like office work in concrete line or field work as inspector or superintendent. Minimum salary desired, $25 per week.

261. Age 37. Student two years in high school; has had correspondence school course and private tuition in mathematics. Has had eighteen years' experience, including surveys and construction of sewers, water works, brick and reinforced concrete buildings, engine and boiler foundations, and large electric conduits; also property and street laying out surveys, drafting of maps, etc. Desires position as chief of party, inspector or draftsman. Salary desired, $4 per day.

262. Age 25. Graduate of University of Maine, 1913, in civil engineering course. Has had two months' experience as levelman on state highway survey in Maine, two months with B. & M. R. R., two months with Pennsylvania R. R., and one month on water-works construction as inspector. Desires position as instrument man. Salary desired, $75 per month.

263. Age 31. Graduate of Mass. Inst. of Technology, civil engineering course; associate member of A. S. C. E. Has had experience on miscellaneous work with U. S. Reclamation Service; as assistant superintendent on construction of electrolytic cells with chemical engineering company; as resident engineer on layout and construction of part of large irrigation canal; and as resident engineer on construction of concrete dam. Desires position as engineer or superintendent on construction or operation; will accept position in minor capacity. Will accept any salary above $60 per month.

264. Age 28. Graduate of Dartmouth College, 1908. Experience includes nearly five years on railway maintenance and construction work, as rodman, transitman, leveler and chief of party; also over a year on municipal work, including large street improvement. Desires position as chief of party or inspector on construction. Salary desired, $90 per month.

265. Age 19. Graduate of Mechanics Arts High School, 1914. Has had no practical experience. Will accept low salary for sake of experience.

LIST OF MEMBERS.

ADDITIONS.

Berry, Charles R. .....4391 Washington St., Roslindale, Mass.
Lane, Edward P. ...5 Vane St., Manchester, Mass.
Mailey, J. Bruce.....20 Howard St., Lynn, Mass.
Wires, Harrison P.....119 Main St., Gloucester, Mass.

CHANGE OF ADDRESS.

Bolton, Edward D.....333 Central Park West, New York, N. Y.
Cook, Mayo T.....149 Glenway St., Dorchester, Mass.
Cunningham, J. Earl.....141 Milk St., Boston, Mass.
Currier, George C.....25 Clifton St., Malden, Mass.
Hatch, Arthur E.,
Care J. S. Packard Dredging Co., Turk's Head Bldg., Providence, R. I.
Kimball, Joseph H.....2d Floor, National Bank Bldg., Dayton, Ohio.
McCurdy, Harry S. R.
Care Morgan Engineering Co., City National Bank Bldg., Dayton, Ohio.
Nolan, Conrad.....10 Whitfield Rd., W. Somerville, Mass.
Sawtelle, Harry F.,
Care Fay, Spofford & Thorndike, 308 Boylston St., Boston, Mass.
Skinner, Fenwick F.....315 West 70th St., New York, N. Y.
Umstead, Charles H.....2804 Hazel St., Texarkana, Tex.
Wiley, Walter T.....80 Carruth St., Dorchester, Mass.

LIBRARY NOTES.

Recent Additions to the Library.

U. S. Government Reports.

Accidents from Falls of Rock or Ore. Edwin Higgins.

Production of Anthracite in 1913. Edward W. Parker.

Production of Barytes in 1913. James M. Hill.

Bibliography of North American Geology for 1913, with subject index. John M. Nickles.

Production of Borax in 1913. Charles G. Yale and Hoyt S. Gale.

Cannonball River Lignite Field, North Dakota. E. Russell Lloyd.

Carnotite near Mauch Chunk, Pennsylvania. Edgar T. Wherry.

Coal Fields in Rhode Island, Virginia, Kentucky and Missouri. G. H. Ashley and others.

Origin of Coal. David White and Reinhardt Thiessen.

Manufacture of Coke in 1913. Edward W. Parker.

Colorado Ferberite and the Wolframite Series. Frank L. Hess and Waldemar T. Schaller.

Electric Lights for Use about Oil and Gas Wells. H. H. Clark.

Fires in Lake Superior Iron Mines. Edwin Higgins.

Production of Fluorspar in 1913. Ernest F. Burchard.

Geology of Phosphate Deposits Northeast of Georgetown, Ida. R. W. Richards and G. R. Mansfield.

Gold Placers on Wind and Bighorn Rivers, Wyoming. Frank C. Schrader.

Gold, Silver and Copper in Alaska in 1913. Alfred H. Brooks.

Gold, Silver, Copper and Lead in South Dakota and Wyoming in 1913. Charles W. Henderson.

Gold, Silver, Copper, Lead and Zinc in Eastern States in 1913. H. D. McCaskey.

Gypsum Industry in 1913. Ralph W. Stone.

Iditarod-Ruby Region, Alaska. Henry M. Eakin.

Production of Lime in 1913. Ralph W. Stone.

Lode Deposits of Alleghany District, California. Henry G. Ferguson.

Production of Magnesite in 1913. Charles G. Yale and Hoyt S. Gale.

Our Mineral Reserves. George Otis Smith.

Production of Mineral Waters in 1913. R. B. Dole.

Mining Districts of Dillon Quadrangle, Montana, and Adjacent Areas. Alexander N. Winchell.

Methods of Oil Recovery in California. Ralph Arnold and V. R. Garfias.

Permissible Electric Lamps for Miners. H. H. Clark.

Pottery Industry in United States in 1913: Statistics. Jefferson Middleton.

Production of Peat in 1913. Charles A. Davis.

Quarry Accidents in United States during Calendar Year 1912. Albert H. Fay.

Quicksilver in 1913. H. D. McCaskey.

Relative Resistance of Various Conifers to Injection with Creosote. C. H. Teesdale.

Resuscitation from Mine Gases: Report of Committee. W. B. Cannon and others.

Production of Salt, Bromine and Calcium Chloride in 1913. W. C. Phalen.

Production of Sand and Gravel in 1913. Ralph W. Stone.

Shinumo Quadrangle, Grand Canyon District, Arizona. L. F. Noble.

Shorter Contributions to General Geology, 1913. David White.

Silver, Copper, Lead and Zinc in Central States in 1913. B. S. Butler and J. P. Dunlop.

Statistics of Railways of United States, 1900-1912.

Transportation of Débris by Running Water. Grove Karl Gilbert.

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Waste of Oil and Gas in Mid-Continent Fields. Raymond S. Blatchley.

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Laconia, N. H. Annual Reports of Board of Public Works for 1912 and 1913.

New York, N. Y. Annual Report of Department of Bridges for 1913.

Providence, R. I. Annual Report of City Engineer for 1913.

Woburn, Mass. Annual Report of Water Department for 1913.

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LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before the 25th of each month.)

Commonwealth of Massachusetts.— METROPOLITAN WATER AND SEWERAGE BOARD. — *Water Works.*

Water-Pipe Tunnel under Chelsea Creek between East Boston and Chelsea.—The excavation and brick lining for the tunnel

which is being constructed by the pneumatic process under Chelsea Creek between East Boston and Chelsea will be completed about November 1, and the work of laying the 42-in. cast-iron pipes and placing the concrete protection around them will then be begun.

Bellevue Reservoir.— The concrete foundation for the Southern Extra High Service Reservoir which is being constructed on the summit of Bellevue Hill, West Roxbury, has been completed by John E. Palmer, of Boston, and the work of erecting the steel tank is now in progress by Walsh's Holyoke Steam Boiler Works of Holyoke. It appears probable that the bottom and lower course of the tank will be lowered on to the foundation about November 1. The tank is 100 ft. in diameter and 44 ft. high, with a capacity of 2 500 000 gal.

Pipe Lines. — Work is in progress on the Southern High Service 24-in. pipe line in Adams St. in Milton under contract with John J. Evans, of Lawrence. The Charles R. Gow Company of West Roxbury has completed the work of laying the Southern Extra High Service 20-in. pipe line in Beech St., West Roxbury, and is now laying connections between this pipe line and the steel tank on Bellevue Hill.

METROPOLITAN WATER AND SEWERAGE BOARD. — *Sewerage Work.* — Work is in progress on Section 69, new Mystic Sewer, at Winchester; on the relief outfall sewer at Nut Island, which consists of 1 400 ft. of 60-in. cast-iron pipe; and on the new screen house at the East Boston Pumping Station.

METROPOLITAN PARK COMMISSION. — The following work is in progress:

Charles River Reservation. — Dredging river from North Beacon St. to Watertown, repairing North Beacon St. bridge and draw and laying submarine cables for police signal system from Charles River Dam to Watertown.

Lynn Shore Reservation. — Repairing sea wall with cement gun.

Middlesex Fells Parkway. — Reconstructing burned portion of Wellington Bridge.

Revere Beach Reservation. — Constructing reinforced concrete shore protection.

Winthrop Shore Reservation. — Constructing sea wall at northerly end of reservation.

City of Boston. — Public Works Department, Highway Division, Paving Service. — Work is in progress on the following streets:

Cambridge St., Washington St. to Warren St., artificial stone sidewalks.
Washington St., Cambridge St. to Union St., artificial stone sidewalks.
Manthorne Rd., Centre St. to Weld St., bituminous macadam.
Kittredge St., Metropolitan Ave. to Cornell St., bituminous macadam.
Pinehurst St., Belgrade Ave. to Dudley Ave., bituminous macadam.
Anawan Ave., Oriole St. to Park St., artificial stone sidewalks.
Oriole St., Anawan Ave. to Park St., artificial stone sidewalks.
Park St., Gilmore Ter. to Boxford Ter., artificial stone sidewalks.
Clement Ave., Meredith St. to Anawan Ave., bituminous macadam.
Rowe St., Ashland St. to Brown Ave., bituminous macadam.
Washington St., Armandine St. to Mora St., bitulithic pavement.
Massachusetts Ave., Columbia Rd. to the R. R. Bridge, granite block paving.
Ulmer St., Arklow St. to Minden St., bituminous macadam.
Avery St., Washington St. to Tremont St., bitulithic pavement.
Dartmouth St., Boylston St. to Newbury St., bitulithic pavement.
Exeter St., Boylston St. to Newbury St., bitulithic pavement.
Seaver St., Walnut Ave. to Humboldt Ave., removing wall.
Frankfort St., Neptune Rd. to Bennington St., bituminous macadam.
Houston St., Montview St. to Crest St., bituminous macadam.

New York, New Haven & Hartford Railroad. — Clinton Mass. Elimination of Grade Crossings. — Work on the B. & M. R. R. now in progress is the erection of a passenger station.

Work on the N. Y., N. H. & H. R. R. is the grading for the permanent embankment, track work, and building fences.

Aberthaw Construction Company. — South Framingham, Mass. — The Printing Building for the Dennison Manufacturing Company is being closed in, Monks & Johnson, engineers. The building is of reinforced concrete frame with brick facing and wooden roof, so arranged that additional concrete floors can be added to the building at a future date.

South Boston. — The cold-storage plant for the Commonwealth Ice and Cold Storage Company at the New Fish Pier is

finished, the last building to be built being the cold-storage building itself. The ice-making plant and the power house have been in commission for some months.

The Fore River Shipbuilding Co., Quincy, Mass., has the following work in progress:

U. S. Battleship *Nevada*.
U. S. Submarine Tender *Fulton*.
Eight U. S. submarine boats.
U. S. Torpedo Boat Destroyers *Cushing* and *Tucker*.

Vol. I DECEMBER, 1914 No. 10

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

NOTICE OF REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on

WEDNESDAY, DECEMBER 16, 1914,

at 7.45 o'clock P.M., in CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. E. R. B. Allardice will present a paper on "The Hydro-Electric Power Plant at the Wachusett Dam," illustrating it with lantern slides. The paper is printed in this number of the JOURNAL.

PAPERS IN THIS NUMBER.

"The Phosphate Rock Industry of Florida," Lester W. Tucker.

(Presented June 10, 1914.)

"The Hydro-Electric Power Plant at the Wachusett Dam, Clinton, Mass.," B. C. Thayer and E. R. B. Allardice.

(To be presented December 16, 1914.)

This number of the JOURNAL also contains a title page, table of contents and index for Volume I.

CURRENT DISCUSSIONS.

Paper.	Author.	Published.	Discussion Closes.
B. & A. R. R. Improvements.	L. G. Morphy.	Nov.	Jan. 15.

JANUARY MEETING OF THE SANITARY SECTION.

A SPECIAL meeting of the Sanitary Section will be held Wednesday, January 6, 1915, at the Society Rooms, Tremont Temple, at 7.45 o'clock P.M.

There will be an informal talk on " Diatoms " under the leadership of Prof. George C. Whipple of Harvard University.

Mr. F. F. Forbes, Superintendent of Water Works of Brookline, will show a collection of microscopic slides, lantern slides and photographs illustrating the various kinds and shapes of these minute vegetable forms found in drinking water, this being made possible with the new stereopticon which permits the use of microscopic slides in the projection microscope, photographs and other opaque objects in the opaque projector as well as the usual lantern slides.

Other meetings are being arranged along similar lines.

FRANK A. MARSTON, *Clerk.*

MINUTES OF MEETING.

BOSTON, November 18, 1914. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order at 8 o'clock by the President, Mr. Harrison P. Eddy.

By vote the reading of the record of the last meeting was dispensed with and it was approved as printed in the November JOURNAL.

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Members: Roy Frederic Bessey, John Joseph Casey, John Seely Grant, Newton LeRoy Hammond, Robert Rand and Julius Waldstein.

Juniors: Ralph Wight Atwater and Frederick Nathaniel Balsor.

The Secretary announced the death of Levi G. Hawkes, a member of the Society, which occurred on November 8, 1914, and by vote the President was requested to appoint a committee to prepare a memoir. The committee appointed consists of Messrs. James E. Stone and Theodore P. Perkins.

After extending a welcome to the members of the American Society of Mechanical Engineers and the Boston Section of the American Institute of Electrical Engineers, who had been invited to join in this meeting, President Eddy introduced the speaker of the evening, Mr. Henry M. Waite, city manager of Dayton, Ohio. Mr. Waite gave a most interesting address on "The Commission-Manager Form of Government and Its Relation to the Engineering Profession." At its close he answered questions in regard to the application of this form of government to the city of Dayton. The President called on ex-Mayor James Logan of Worcester, who related some of his experiences as mayor of that city. On motion of Past President Stearns, the thanks of the Society and of the others present were extended to Mr. Waite by a unanimous vote.

The total attendance was 396.

Adjourned.

S. E. Tinkham, *Secretary.*

APPLICATIONS FOR MEMBERSHIP.

[December 5, 1914.]

The By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a

just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

ALDEN, FREDERICK THORNTON, Malden, Mass. (Age 25, b. Malden, Mass.) Graduate of Mass. Inst. of Tech., 1912, civil engineering course. From July, 1912, to March, 1913, inspector of sewer construction and draftsman with city engineer of Malden; from March to July, 1913, draftsman with Ambursen Hydraulic Construction Company; from July, 1913, to April, 1914, inspector and draftsman, and from April, 1914, to date, assistant city engineer, city of Malden. Refers to C. F. Allen, H. L. Coburn, H. W. Estey, Dwight Porter and C. M. Spofford.

BAKER, LLOYD ELLIOT, Providence, R. I. (Age 26, b. Hyannis, Mass.) Graduate of Technical High School, Providence, 1907. From July 1, 1907, to February, 1913, with Street Line, Parks and Public Bldgs. Dept., Providence, first as rodman and later as transitman; from February to June, 1913, with Bridge and Harbor Dept. as assistant engineer on construction of bulkhead at Fields Point; from June, 1913, to date, assistant engineer with Highway Dept. Refers to F. B. Bourne, W. A. Brown, O. F. Clapp, H. J. Reynolds and I. S. Wood.

BARNES, RODERICK STUART, Albany, N. Y. (Age 28, b. Morgan, Vt.) Graduate of Mexico, Me., High School, 1904. From 1904 to 1906, with S. A. Reed, civil engineer and surveyor; from March, 1907, to July, 1911, with Buzzell Bros. Construction Co., Randolph, N. H., on construction work, state highways and bridges; from July, 1911, to date, with U. S. Geological Survey, Water Resources Branch; at present engaged in study of water resources of Massachusetts. Refers to L. F. Cutter, F. H. Fay, C. H. Pierce, S. E. Tinkham and F. I. Winslow.

BLACKMER, ARTHUR ELIOT, Plymouth, Mass. (Age 40, b. Plymouth, Mass.) Graduate of Mass. Inst. of Technology, Course I, Class of 1899. From 1900 to 1902, railroad engineering assistant; from 1902 to date, superintendent of water works, and from 1906 to date, town engineer, Plymouth, Mass. Refers to C. F. Allen, J. E. Carty, L. S. Cowles, F. H. Fay, Dwight Porter and F. I. Winslow.

BROWN, WILLIAM AUGUSTUS, East Boston, Mass. (Age 22, b. East Boston, Mass.) Graduate of Mechanic Arts High School; at present student

in structural engineering at Lowell Institute. From July, 1910, to August, 1911, draftsman with New England Tel. & Tel. Co., plant department, from August, 1911, to February, 1913, draftsman and inspector of conduit construction with Edison Electric Illuminating Co.; from March to November, 1913, draftsman on building construction with General Electric Co., West Lynn; from March to October, 1914, draftsman in construction department, Swift & Co.; from November, 1914, to date, draftsman on building construction with Aberthaw Construction Co. Refers to A. B. MacMillan, W. D. Morrill, F. A. Snow and J. E. Stone.

Brownell, Walter Keith, Brookline, Mass. (Age 26, b. Brookline, Mass.) Graduate of Mass. Inst. of Tech., 1910, civil engineering course. During college course served for two summers as rodman for State on construction work; for one year following graduation was assistant in civil engineering, Mass. Inst. of Tech.; was six months on railroad valuation and six months with city surveyor, New York City; since July, 1912, has been with Stone & Webster Engineering Corporation on drafting and construction work; during past year has been squad chief on concrete structure, new Technology buildings. Refers to H. K. Alden, C. F. Allen, R. D. Bradbury, W. W. Clifford, C. E. Nichols and C. M. Spofford.

Bussey, Byron Chapman, Pawtucket, R. I. (Age 26, b. Central Falls, R. I.) Graduate of Pawtucket High School, 1906. From June, 1906, to date, with city engineer, Pawtucket, R. I.; has served as rodman, transitman, levelman and inspector, and is now assistant engineer. Refers to G. A. Carpenter, F. H. Carter, F. A. Sweet and F. E. Waterman.

Cherry, Martin Charles, Roslindale, Mass. (Age 24, b. Roslindale, Mass.) Graduate of Mechanic Arts High School, 1908; student at Mass. Inst. of Technology, 1908–09. From June, 1909, to May, 1913, rodman and instrumentman with Boston Elevated Ry. Co., Dept. of Elevated and Subway Construction; from May, 1913, to date, inspector with Boston Transit Commission. Refers to E. S. Davis, C. T. Fernald, L. L. Street and W. O. Wellington.

Chubbuck, Herman F., So. Boston, Mass. (Age 55, b. Nevada, Cal.) Educated in Boston public schools. From 1872 to 1889, employed at Lewis Wharf Warehouse, first as boy, later as clerk, and finally as storekeeper; from 1889 to date, foreman and superintendent of construction for various Boston contractors. Refers to E. P. Adams, C. J. Carven, A. O. Doane, F. L. Fuller and J. E. Stone.

Cochran, William J., Boston, Mass. (Age 22, b. Boston, Mass.) Graduate of Mechanic Arts High School, 1911; student at Lowell Institute two years, 1912 and 1913. From August, 1911, to May, 1913, with Aspinwall & Lincoln, as rodman and instrumentman; from May, 1913, to date, with Boston Transit Commission; is now instrumentman, chief-of-party and inspector on Section G, East Boston Tunnel Extension. Refers to Thomas Aspinwall, E. S. Davis, L. L. Street and W. O. Wellington.

Dalton, Marshall Bertrand, Boston, Mass. (Age 21, b. Portland,

Me.) Is fourth-year student at Mass. Inst. of Technology. Refers to C. F. Allen, C. B. Breed, H. P. Eddy and G. L. Hosmer.

De Merritt, Robert Elwyn, Reading, Mass. (Age 21, b. Orange, Mass.) Third-year student at Mass. Inst. of Tech., civil engineering course, Rodman with C. E. Carter, Reading, for four months. Refers to C. E. Carter, G. L. Hosmer, J. W. Howard, A. G. Robbins, G. E. Russell and C. M. Spofford.

Dolliver, Henry Francis, Lawrence, Mass. (Age 28, b. South Framingham, Mass.) Graduate of Mass. Inst. of Tech., 1911, civil engineering course. From 1911 to date, with Aberthaw Construction Co., Boston, on outside construction work; has served as timekeeper, engineer, chief clerk in job office, and on efficiency work in "making-up" of concrete forms, in summer of 1914 superintended small job done by Aberthaw Construction Co. for Taunton Oil Cloth Co.; at present in charge of field office on construction of five-story concrete and structural steel building for Fore River Shipbuilding Corporation. Refers to A. B. MacMillan, Dwight Porter, J. M. Sokoll. C. M. Spofford and L. C. Wason.

Duffy, John Henry, Cambridge, Mass. (Age 28, b. Somerville, Mass. Graduate of Lexington High School, 1904; received technical education from I. C. S. courses and at Franklin Union. From 1905 to date, with county of Middlesex engineering department, first as rodman, later as transit man, chief-of-party and finally, assistant engineer, the work involving, chiefly, the survey, location and construction of highways and appertaining structures; is now resident engineer on construction of reinforced concrete bridge and 4 000 ft. of highway adjacent thereto. Refers to H. S. Adams, B. S. Brown, C. H. Gannett and F. H. Kendall.

Durgin, Clyde M., Roslindale, Mass. (Age 35, b. Poland, Me.) Received technical education from I. C. S., Y. M. C. A., Lowell Inst., and Franklin Union courses. From 1900 to 1905, draftsman on general power plant work with Edison Electric Illuminating Company; was for six months with B. F. Sturtevant Company of Hyde Park on economizer layout and structural work; from 1906 to 1907, draftsman with Holmes & Blanchard, Boston; from 1907 to 1908, draftsman with Stone & Webster Engineering Corporation on power station, structural steel and railway work; from 1908 to 1909, draftsman on electrical work with Schoolhouse Department, city of Boston; from 1909 to date, with Stone & Webster Engineering Corporation in charge of masonry design and drafting with some station equipment work; at present in charge of squad on concrete detailing, new Technology buildings. Refers to H. K. Alden, E. F. Allbright, W. W. Clifford, J. H. Libbey and C. E. Nichols.

Eberhard, Walter C., Roslindale, Mass. (Age 22, b. Roslindale, Mass.) Graduate of Mechanic Arts High School, Boston, 1910, and of Mass. Inst. of Tech., 1914, civil engineering course; course at Inst. included work at summer school of surveying. At present assistant in civil engineering department of Mass. Inst. of Tech. Refers to C. F. Allen, C. B. Breed, G. L. Hosmer, J. W. Howard and A. G. Robbins.

EDDY, HARRISON PRESCOTT, JR., Newton Centre, Mass. (Age 19, b. Worcester, Mass.) Student at Mass. Inst. of Technology, 1913–14. Refers to C. M. Allen, H. P. Eddy, A. L. Fales, Leonard Metcalf, F. A. Marston and C. W. Sherman.

EDGAR, CHARLES LEAVITT, Brookline, Mass. (Age 54, b. Griggstown, N. J.) Graduate of Rutgers College, 1882; given honorary degree, Electrical Engineer, by college, 1887. From 1883 to 1887, chief engineer, parent Edison Electric Light Company; 1887 to date, general superintendent, general manager, vice-president and president of Edison Electric Illuminating Company of Boston. Refers to L. S. Cowles, I. N. Hollis, Sydney Hosmer, D. C. Jackson, C. T. Main and I. E. Moultrop.

FARWELL, ROBERT BENNESON, Boston, Mass. (Age 43, b. Quincy, Ill.) Graduate of Worcester Polytechnic Inst., 1893, civil engineering course. From 1893 to 1894, on surveys for mill plants and general municipal surveys, Jewett City and Norwich, Conn., from 1894 to 1898, with Boston Transit Comm. on construction of Tremont Street subway; from 1899 to 1902, with sewer division of Street Department, Boston, on calculations and designs; from 1902 to 1908, with Boston Transit Comm. as assistant engineer in charge of various sections in East Boston and Washington Street tunnels; from 1909 to 1911, with Boston Elevated Railway Co., as division engineer in charge of Cambridgeport division of Cambridge subway; from 1911 to date, with Boston Transit Comm. in charge of East Boston tunnel extension. Refers to H. A. Carson, E. S. Davis, E. S. Dorr, G. C. Emerson, C. R. Gow and J. R. Worcester.

GALLENE, VICTOR JOSEPH, Fall River, Mass. (Age 23, b. Italy.) Graduate of Mass. Inst. of Tech., 1914, civil engineering course. During summer of 1911, draftsman with New England Tel. & Tel. Co.; summer of 1912 attended Mass. Inst. of Tech. summer school in Maine; summer of 1913 with Wilson & Tomlinson Construction Co. of Boston on reinforced concrete; is now with Barrows & Breed on reinforced concrete conduits in Fall River. Refers to H. K. Barrows, C. B. Breed, A. L. Shaw and C. M. Spofford.

GRAY, THOMAS F., Malden, Mass. (Age 43, b. New York, N. Y.) Educated in public schools. Has had ten years' practical experience in civil engineering in state of Wyoming; in charge of party on field work of Shoshone irrigation survey; licensed irrigation engineer, state of Wyoming; at present advanced student of surveying and civil engineering. Refers to E. P. Adams, S. L. Connor, F. B. Sanborn and J. E. Stone.

GRIFFIN, JOHN HENRY, Gloucester, Mass. (Age 36, b. Gloucester, Mass.) Graduate of public schools of Gloucester. In 1896 entered city engineer's office as assistant; is now city engineer of Gloucester. Refers to R. C. Allen, W. W. Drummond, E. A. W. Hammatt, C. F. Powers and H. P. Wires.

HAKES, JESSE FRANKLIN, Baltimore, Md. (Age 25, b. Westerly, R. I.) Graduate of Mass. Inst. of Technology, 1912, in civil engineering course.

From June, 1912, to December, 1913, student of railway operation with B. & O. R. R.; from January to July, 1914, engineer with T. B. Howard & Co., Nashville, Tenn.; from July, 1914, to date, efficiency engineer with Baltimore Tube Co. Refers to C. F. Allen, C. B. Breed, C. R. Elkins and H. R. Hall.

HANNA, JOHN BAXTER, Pawtucket, R. I. (Age 23, b. Pawtucket, R. I.) Graduate of Pawtucket High School. From September, 1909, to date, with city engineer of Pawtucket; has served as transitman, levelman, computer, draftsman and assistant engineer on sewer and highway construction. Refers to G. A. Carpenter, F. H. Carter, F. A. Sweet and F. E. Waterman.

HARRINGTON, WALTER, Plainfield, N. J. (Age 20, b. Cleveland, Ohio.) Student at Mass. Inst. of Tech., Class of 1917. Refers to H. P. Eddy.

HAYES, JAMES, JR., Brockton, Mass. (Age 32, b. Brockton, Mass.) Graduate of Mass. Inst. of Technology, 1906, department of civil engineering. From September, 1906, to September, 1910, with Charles River Basin Commission in various capacities, as rodman, transitman and draftsman in field and office work; during winter of 1910–11, with Smith & Lovett Co., structural steel and iron workers, as draftsman, designer and estimator; from June, 1911, to January, 1913, civil engineer with Massachusetts Highway Commission; from January, 1913, to February, 1914, city engineer of Brockton; from February, 1914, to date, in private practice as civil engineer at Brockton. Refers to W. N. Charles, J. N. Ferguson, A. J. Holmes, J. L. Howard and A. M. Lovis.

HOOVER, WALTER T., Brookline, Mass. (Age 29, b. New York, N. Y.) Student of Mass. Inst. of Tech. from 1903 to 1905, Course I. From 1905 to 1907, worked with State Board of Health; during part of 1907, with Stone & Webster Engineering Corporation on statistics engineering; in fall of 1907 began business for himself as sales representative for various paint companies; is now New England sales agent for Detroit Graphite Company. Refers to F. H. Fay, W. S. Johnson, J. F. Osborn and H. E. Sawtelle.

HOSMER, CHARLES IRWIN, Turners Falls, Mass. (Age 28, b. Turners Falls, Mass.) Student at University of Vermont, 1906 to 1908; graduate of Mass. Agricultural College, 1910, civil engineering course. During summer of 1907, transitman for Keith Paper Co., Turners Falls, Mass.; during summers of 1908 and 1909, transitman on surveys for town of Montague; from July, 1910, to May, 1911, assistant engineer with Keith Paper Co.; from May, 1911, to January, 1912, assistant engineer with Worcester Suburban Electric Co., Uxbridge, Mass.; from January, 1912, to date, engineer with Turners Falls Co. Refers to J. R. Baldwin, C. W. Hazelton, H. A. Moody and A. T. Safford.

IVES, HOWARD CHAPIN, Worcester, Mass. (Age 36, b. Cheshire, Conn.) Graduate of Sheffield Scientific School of Yale Univ., with degree of Ph.B. in 1898 and C.E. in 1900. In engineering practice from 1898 to 1900 and during several summers since; from 1900 to 1903, instructor in civil engineering, Worcester Polytechnic Inst.; from 1903 to 1906, assistant professor of

civil engineering, University of Pennsylvania; from 1906 to 1912, assistant professor of railroad engineering, Worcester Polytechnic Inst.; and from 1912 to date, professor of railroad engineering in that institution; author of "Surveying Manual," joint author with A. W. French of "Stereotomy," and joint author with H. E. Hilts of "Problems in Surveying, Railroad Surveying and Geodesy." Refers to C. M. Allen, H. P. Eddy, A. W. French, I. N. Hollis and F. A. Marston.

KNIGHT, ARTHUR J., JR., Worcester, Mass. (Age 29, b. Worcester, Mass.) Received education in Worcester public schools and at Worcester Polytechnic Inst., graduating from latter in 1907. From June, 1907, to June, 1908, masonry inspector on construction with Northern Pacific Railway Company; from June, 1908, to July, 1910, resident engineer with same company on reconstruction, valuation and relocation; from Sept., 1910, to date, instructor in civil engineering, Worcester Polytechnic Inst.; during summer of 1911, in charge of field party on boundary and road survey of Northbridge, Mass.; during summers of 1913 and 1914, resident engineer on construction of Worcester Polytechnic Inst. athletic field. Refers to C. M. Allen, A. W. French, I. N. Hollis and F. A. Marston.

KNOWLTON, ARTHUR WILLIAM, Rockport, Mass. (Age 24, b. Boston, Mass.) Graduate of Worcester Polytechnic Inst., 1914. From July 6, 1914, to date, assistant bridge inspector, fourth division, B. & M. R. R. Refers to C. M. Allen, Frederic Bonnet, Jr., E. A. Norwood and H. P. Wires.

LAKE, HARRY ELEAZER, Boston, Mass. (Age 30, b. Topsfield, Mass.) Graduate of Mass. Inst. of Tech., 1911, civil engineering course. From June to September, 1906, inspector on sewerage system construction, Whitinsville, Mass.; from March, 1906, to June, 1911, engaged in private surveying practice during spare time; during summer of 1909, engineer inspector with Boston Insulated Wire Co.; from August, 1911, to October, 1912, efficiency engineer for W. H. McElwain Co. in layout of new factory in Manchester, N. H.; from November, 1912, to November, 1914, assistant at Lowell Astronomical Observatory; is now secretary to fire prevention commissioner for Metropolitan District. Refers to G. L. Hosmer, L. E. Moore, A. G. Robbins and C. M. Spofford.

MCAULIFFE, JOHN AUGUSTIN, Boston, Mass. (Age 24, b. Providence, R. I.) Graduate of Tufts College, 1913, civil engineering course. During college course worked four months as foreman over section of concrete gang with Hugh Nawn Contracting Co. and four months as draftsman with New England Structural Co.; worked one month with latter company after graduation; from July, 1913, to January, 1914, with Mead-Morrison Mfg. Co. as inspector of machine work and in contracting department; from January, 1914, to date, with Henry A. Wentworth, cons. engr., Boston. Refers to S. L. Connor, E. H. Rockwell, F. B. Sanborn and R. C. Smith.

MELLOR, ALFRED RAINFORD, Boston, Mass. (Age 28, b. Fall River, Mass.) Graduate of Cornell University, 1911, degree of C.E. From 1911 to 1912, with city eng'r'g dept., New Bedford, Mass.; from 1912 to 1914,

with Massachusetts Harbor & Land Comm. Refers to L. H. Bateman, C. F. Powers, A. P. Rice, F. N. Wales and W. F. Williams.

MILLER, CHARLES AUGUSTUS, Wollaston, Mass. (Age 44, b. Boston, Mass.) Educated in Boston public schools and at South Boston School of Art. Has been with William L. Miller for twenty-two years; is now general manager. Refers to C. R. Gow, E. S. Larned, J. W. Rollins and S. E. Tink ham.

PATTON, EUGENE STEWART, Pawtucket, R. I. (Age 39, b. North Adams, Mass.) From May, 1894, to date, with city engineering department, Pawtucket, R. I., chiefly on sewer work, including sewage disposal and design, construction, inspection and maintenance of sewers. Refers to G. A. Carpenter, F. H. Carter, F. A. Sweet and F. E. Waterman.

PERLEY, LEW KNOWLTON, Laconia, N. H. (Age 24, b. Laconia, N. H.) Graduate of Dartmouth College, 1912, degree of B.S., and of Thayer School of Civil Engineering, 1913, degree of C.E.; member of Gamma Alpha Scientific Society and Thayer Society of Civil Engineers. From time of graduation to September, 1913, with Aberthaw Construction Co. of Boston; from September, 1913, to January, 1914, with Massachusetts State Highway Comm.; since January, 1914, has been located in Laconia, N. H., as private engineer, work consisting mostly of surveying and mapping. Refers to A. W. Dean, C. A. French, A. E. Hoxie and A. M. Lovis.

PERRY, CHAUNCY RUSCH, Waltham, Mass. (Age 42, b. Waltham, Mass.) From 1890 to 1892, in drafting office of Boston Bridge Works; from 1892 to 1895, student in Lawrence Scientific School, Harvard Univ., graduating in 1895; from 1895 to 1898, assistant engineer with Boston Transit Comm.; from 1898 to 1901, assistant engineer with J. R. Worcester; from 1901 to 1906, first assistant engineer, estimating department, Boston Bridge Works; from 1906 to 1909, assistant engineer with Boston Transit Comm.; from 1909 to date, with J. R. Worcester & Co. Refers to M. F. Brown, H. A. Carson, E. S. Davis, H. B. Pratt, E. H. Rockwell and J. R. Worcester.

PINKHAM, MILLARD BARTLETT, Roxbury, Mass. (Age 21, b. South Harpswell, Me.) Senior at Mass. Inst. of Tech., civil engineering course. Refers to G. L. Hosmer, J. W. Howard, Dwight Porter, G. E. Russell and C. M. Spofford.

PREBLE, FRANK LINWOOD, Waltham, Mass. (Age 56, b. Charlestown, Mass.) Served about four years in city engineer's office, Somerville, Mass.; three years in office of Charles F. Parks, civil engineer, Waltham, Mass., and two years in civil engineer's office, U. S. Navy, Portsmouth, N. H.; has been for twenty-nine years with William Wheeler, construction engineer, on waterworks construction, etc., as resident engineer on works. Refers to H. P. Eddy, F. A. Marston, C. W. Sherman and William Wheeler.

PROCTOR, FRED W., North Adams, Mass. (Age 31, b. Wilton, N. H.) Graduate of Tufts College, 1906, civil engineering course. From September, 1906, to January, 1910, with B. & M. R. R., as transitman, inspector on separation of grades at Williamstown, West Deerfield, South Vernon and

Springfield, and assistant engineer; from January, 1910, to August, 1912, surveyor of Mt. Auburn Cemetery; from August, 1912, to February, 1913, assistant city engineer, North Adams; appointed superintendent of streets, February, 1913: since July, 1914, has been city engineer and acting superintendent of streets. Refers to F. H. Carter, W. S. Johnson, F. B. Locke, J. F. Peterson, J. C. Scorgie and F. B. Sanborn.

RAYMOND, JOHN WILLIAM, Jr., Beverly, Mass. (Age 24, b. Chicago, Ill.) Graduate of Mass. Inst. of Tech., 1912, civil engineering course. From 1912 to date, with city engineer of Lynn, Mass.; during 1912 and 1913, in charge of survey of city to be used for assessors' purposes; during past year in charge of construction of dams at Breed's Pond in connection with increased water storage system of Lynn. Refers to H. K. Barrows, C. B. Breed, H. P. Burden, Sidney Smith, R. H. Sutherland and W. L. Vennard.

SKILLIN, FRED BURGESS, Somerville, Mass. (Age 26, b. Boston, Mass.) Graduate of Tufts College, 1911, with degree of B.S. in civil engineering. While attending school worked five summers with B. & M. R. R., one as rodman on land surveys, construction and general maintenance, four on carpenter work in B. & B. Dept.; from August, 1911, to February, 1912, rodman with B. & M. R. R.; from February to April, 1912, assistant to foreman in machine shop, F. S. Payne Company; from May, 1912, to May, 1913, with B. & M. R. R. as recorder, on clearance survey, architectural draftsman and rodman; from May, 1913, to January, 1914, draftsman, computer, etc., with C. E. Carter, of Reading, Mass., from February to August, 1914, research man with valuation department of B. & M. R. R.; from August, 1914, to date, with Interstate Commerce Comm. as computer in valuation department. Elected a junior December 20, 1911, and now desires to be transferred to grade of member. Refers to L. H. Allen, C. E. Carter, T. P. Perkins, F. B. Rowell, F. B. Sanborn and F. C. Shepherd.

SMITH, STANLEY ARMSTRONG, Somerville, Mass. (Age 23, b. Dorchester, Mass.) Graduate of Mass. Inst. of Tech., 1914, architectural engineering course. Summer work during college course as follows: 1911, draftsman and squad chief with New England Tel. & Tel. Co.; 1912, engineer and draftsman with Hanscom Construction Co.; 1913, draftsman on construction with Lockwood, Greene & Co.; from July to November, 1914, with Stone & Webster Engineering Corporation as draftsman on reinforced concrete and steel work; from November, 1914, to date, draftsman with Aberthaw Construction Co. Refers to H. K. Alden, H. W. Hayward, E. R. Hyde, W. H. Lawrence, A. B. MacMillan and J. R. Worcester.

STONE, GEORGE CARTER, Dorchester, Mass. (Age 27, b. Hurt, Va.) Graduate of Virginia Polytechnic Inst., B.S. 1908, C.E. 1909, and of Cornell University, C.E. 1911; specialized in hydraulic and water-power engineering and in reinforced concrete construction. From June, 1911, with Lockwood, Greene & Co., as draftsman, detailer, checker and estimator on plans for development and extension of various industrial plants; is Junior, Am. Soc.

C. E. Refers to C. S. Allen, L. H. Allen, A. B. MacMillan, E. F. Rockwood and F. E. Shedd.

STUART, GEORGE EDWIN, Newton, Mass. (Age 58, b. Waverley, Mass.) Graduate of Newton public schools. Was for thirty-five years deputy street commissioner, city of Newton; from April 16, 1914, to date, street commissioner. Charter member and president in 1910 of Massachusetts Highway Association. Refers to Dexter Brackett, I. W. Hastings, W. P. Morse, J. R. Roblin, E. H. Rogers and L. K. Rourke.

THOMAS, HOWARD CUSHING, Wellesley Hills, Mass. (Age 21, b. Somerville, Mass.) Senior at Mass. Inst. of Technology; spent part of one summer at Technology Surveying Camp; during past three summers has been employed by W. W. Wight, C.E., Wellesley Hills. Refers to C. B. Breed, F. L. Fuller, G. L. Hosmer, J. W. Howard, G. E. Russell and W. W. Wight.

TOSI, JOSEPH ANDREW, Worcester, Mass. (Age 25, b. Boston, Mass.) Graduate of Tufts College, 1913, with degree of B.S. in structural engineering. From Oct., 1913, to date, with E. J. Cross Co., contractors and builders, Worcester; began as timekeeper; Nov., 1913, put in charge of erecting steel on Norton Co.'s new clay plant, Greendale, Mass.; has since been engineer on foundations at Worcester Country Club and engineer in charge of steel reinforcement and concrete at Union Twist Drill job, Athol, Mass.; is now in charge of erection of small addition to Mills Woven Cartridge Belt Co.'s factory, Worcester. Refers to E. H. Rockwell, F. B. Sanborn and R. C. Smith.

WALES, WINTHROP LODGE, West Roxbury, Mass. (Age 28, b. North Abington, Mass.) Graduate of Tufts College, 1910, with degree of B.S. in structural engineering. After graduation worked with Whidden Construction Company of Boston, drafting, designing and superintending construction; from May, 1911, to May, 1913, engineer and salesman with Snow Iron Works Company; from May, 1913, to date, structural designer with Stone & Webster Engineering Corporation. Refers to S. L. Conner, E. H. Rockwell, F. B. Sanborn and R. C. Smith.

WORCESTER, ROBERT JOSEPH HENDERSON, Concord, Mass. (Age 32, b. Boston, Mass.) Education obtained chiefly in elementary schools and from I. C. S. and other private courses; student for one-half year at Seton Hall College, South Orange, N. J. From June, 1899, to Dec., 1900, was U. S. naval apprentice; from May, 1901, to May, 1904, with U. S. cavalry, serving two years in Philippine Islands, where, as corporal and sergeant, had charge of considerable road building; from July, 1904, to Dec., 1904, timekeeper and foreman with Newark (N. J.) Paving Co.; from Jan., 1905, to Dec., 1909, with Westinghouse, Church, Kerr & Co. on various engineering projects, as inspector, rodman, instrumentman, chief-of-party, etc.; from Dec., 1909, to Jan., 1910, steel foreman with Eastern Concrete Construction Co., Hartford, Conn.; from Feb., 1910, to July, 1910, with Aberthaw Construction Co. at Buffalo, N. Y., as steel and concrete foreman; from July, 1910, to May, 1913,

with Westinghouse, Church, Kerr & Co. as assistant superintendent on power house construction, and assistant engineer or superintendent on several small jobs; is now on second year as superintendent of roads and bridges for town of Concord, Mass. Refers to E. J. Beugler, G. W. Burpee, J. M. Keyes, L. W. Tucker and J. R. Worcester.

LIST OF MEMBERS.

ADDITIONS.

Ambrose, George C., care Boston Con. Gas Co., 17 Hilton St., Roxbury, Mass.
Casey, John J. .... 79 Howland St., Roxbury, Mass.
Ell, Carl S. .... 316 Huntington Ave., Boston, Mass.
French, Arthur W. .... Worcester Polytechnic Inst., Worcester, Mass.
Lyons, Timothy R. .... 270 Lake Ave., Manchester, N. H.
Maconi, Gaetano. .... 76 Clark St., Newton Centre, Mass.
Peaslee, Dana N. .... 73 Baker St., Lynn, Mass.
Robinson, Harold L. .... 75 Washington St., Winchester, Mass.
Runels, Ralph E. .... 321 Thorndike St., Lowell, Mass.
Sawyer, George S. .... 199 No. Main St., Fall River, Mass.
Smith, Arthur H. .... 31 Milk St., Boston, Mass.
Stone, Leo S. .... 106 Waumbeck St., Roxbury, Mass.
Stott, Samuel E. .... 60 No. Market St., Boston, Mass.

CHANGE OF ADDRESS.

Alexander, E. Porter .... 418 Manhattan Bldg., Duluth, Minn.
Allbright, Edwin F. .... 124 Faxon Road, Atlantic, Mass.
Bowers, George W. .... 1414 West 85th St., Cleveland, Ohio.
Campbell, Charles A. .... 19 Hubbard Road, Dorchester, Mass.
Coburn, William H. .... 396 Ward St., Newton Centre, Mass.
Drake, Henry P., care Water Supply Comm. of Pennsylvania,
Telegraph Bldg., Harrisburg, Pa.
Haggett, Harold D. .... Engrg. Dept., Maine Central R. R., Portland, Me.
Hammond, Wilberforce B. .... 32 Center St., Brookline, Mass.
Jeffers, Robert B. .... care West End Y. M. C. A., Toronto, Canada.
Mann, John L. .... 51 Chambers St., New York, N. Y.
Rice, George S. .... 50 Court St., Brooklyn, N. Y.
Richardson, Lyle M. .... 72 Shelton Ave., New Haven, Conn.
Tupper, Fred E. .... 18 Spear St., Quincy, Mass.
Umstead, Charles H. .... care New Federal Bldg., Port Jarvis, N. Y.
Yates, Sheldon S. .... Branford, Conn.

DEATHS.

Hawkes, Levi G. .... Died November 8, 1914
Taylor, Lucian A. .... Died November 19, 1914

EMPLOYMENT BUREAU.

THE Board of Government has established an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society rooms two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

MEN AVAILABLE.

182. Age 23. High school graduate and has taken courses at Boston Y. M. C. A. and Franklin Union. Has had more than two years' experience in engineering work, including nine months as rodman with B. & M. R. R., seven months with Massachusetts Highway Comm., and eleven months with B. & A. R. R. as transitman, draftsman and chief-of-party. Will accept either permanent or temporary position. Salary desired, $65 per month.

266. Age 30. Graduate engineer, University of Michigan. Served apprenticeship with Carnegie Steel Co., Youngstown, Ohio; worked in steel mills every summer while student, beginning at age of fourteen as blue-print boy and working in different departments; experience includes systematizing of plants for one of largest banks in Middle West at Milwaukee, Wis.; taking full charge of erecting steel and ornamental iron in Wisconsin's state capitol; designing of steel work for fish pier, South Boston; and three years' teaching of machine shop work. Prefers position as efficiency or sales engineer. Chance for future advancement more important than salary.

267. Age 31. Graduate of high school and student for one year at Mass. Inst. of Technology. Experience includes one year's work as rodman and three as transitman with prominent engineer; two months as draftsman with Charles River Basin Commission; and more than four years on engineering force of up-to-date Massachusetts town, during which time he has served as transitman, draftsman, inspector and party leader. Desires position as transitman, party leader or inspector. Salary desired, $75 per month.

268. Age 24. Graduate of Tufts College Engineering School, 1914, with degree of B.S. Has had one and one-half years' experience with New England Telephone Co. and three months' experience with Edison Electric Illuminating Co. of Boston, working as draftsman in both instances; experience includes both electrical and civil engineering work. Will accept any kind of engineering work. Minimum salary desired, $15 per week.

269. Age 25. Graduate of Dorchester High School, also of Franklin Union in civil engineering course in structures. Has had two years' experience as structural draftsman with Fore River Shipbuilding Co., and five years' experience as structural detailer and draftsman with Boston Elevated Ry. Co.

Desires position as structural draftsman or detailer. Salary desired, $100 per month.

270. Age 36. Educated in high and private schools. Has had about fifteen years' experience in drafting, construction and surveys, including considerable railway work in Central and South America, and five years with General Electric Co. of Lynn as draftsman in building department. Desires position as draftsman or on construction work. Salary desired, $20 per week.

271. Age 24. Graduate of Tufts College Engineering School, with degree of B.S. in structural engineering. Experience includes field work with Directors, Port of Boston, on Belt Line Survey, construction work on East Boston Tunnel Extension, and a year and four months on plans for all varieties of concrete construction. Desires position as designer on steel or concrete work, or clerical work in engineering office which will include supervision of outside work.

272. Age 33. Graduate of Mass. Inst. of Technology, 1904, in Civil Engineering Course.

273. Age 24. Graduate of Mass. Inst. of Tech. Has had over two years' experience, including four months with New England Telephone and Telegraph Company, six months with consulting engineer and eighteen months with large engineering corporation. Desires position as reinforced concrete designer or detailer. Salary desired, $25 per week.

274. Graduate of Mass. Inst. of Tech., hydraulic and electrical engineer. Has had experience in construction of electric and hydraulic machinery in factories of this country and Germany, also ten years' general consulting experience in application of such for power and industrial plants. Member of B. S. C. E. and of A. S. M. E.; Fellow of A. I. E. E.

275. Age 19. Student for three years in Somerville High School and for one year at Lowell Inst. Has had two years' experience with structural engineering firm as estimator, tracer, draftsman, etc. Desires position involving some responsibility and with chance of advancement. Salary desired, $12 per week.

276. Age 32. Has taken four years' evening technical course at Boston Y. M. C. A., also course at Lowell Inst. for industrial foreman. Has had sixteen years' experience with various machine manufacturing companies, chiefly on machine and tool design; has had considerable experience as assistant to superintendent. Desires position as machine and tool designer or as assistant superintendent. Salary desired, $20 to $30 per week.

277. Age 31. Student for two years at Mass. Inst. of Tech. Has had two years' experience on railroad survey and construction in Massachusetts and ten years' experience in railroad and mining work in Mexico, including experience as contractor's superintendent; considers himself good instrumentman, fair draftsman and successful in handling labor; speaks Spanish, will go anywhere. Desires position as assistant to engineer or contractor; will accept temporary position. Salary no object if there is a chance to work up.

LIBRARY NOTES.

Recent Additions to the Library.

U. S. Government Reports.

Effects of Varying Certain Cooking Conditions in Producing Soda Pulp from Aspen. Henry E. Surface.

Judicial Recall. Rome G. Brown.

Study of the Oxidation of Coal. Horace C. Porter and O. C. Ralston.

State Reports.

Massachusetts. Harbor and Land Commission's Atlas of Boundary Lines of Cities of North Adams and Pittsfield and Towns of Adams, Cheshire, Clarksburg, Dalton, etc.

Massachusetts. Report of Public Service Commission on Middlesex and Boston Rate Case, 1914.

New York. Annual Report of Public Service Commission for First District for 1912, Vol. III.

Pennsylvania. Wood-Using Industries, 1912. Robert S. Conklin.

City and Town Reports.

Cambridge, Mass. Annual Report of Water Board for 1913.

Marlborough, Mass. Annual Report of Water and Sewage Commission for 1913.

Philadelphia, Pa. Annual Report of Bureau of Surveys for 1913.

Miscellaneous.

American Society for Testing Materials: Year Book for 1914. Gift of L. C. Wason.

Canada, Department of Mines: Copper Smelting Industries of Canada, by Alfred W. G. Wilson; Lode Mining in Yukon by T. A. MacLean.

Institution of Civil Engineers (London): Minutes of Proceedings, Volumes CXCV and CXCVI.

Municipal Engineers of City of New York: Brass in Engineering Construction, by Alfred D. Flinn.

(The) War and Wall Street. W. C. Van Antwerp.

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before the 1st of each month.)

Commonwealth of Massachusetts. — METROPOLITAN WATER AND SEWERAGE BOARD. — *Water Works.*

Water-Pipe Tunnel under Chelsea Creek between East Boston and Chelsea. — The excavation and brick lining for the tunnel were completed November 18. The work of laying the 42-in. cast-iron pipes and placing concrete protection around them is now in progress under free air.

Bellevue Reservoir. — The bottom and lower course of the steel tank (100 ft. in diameter by 44 ft. high) that is being constructed on Bellevue Hill in West Roxbury has been lowered on the foundation and the joint filled with Portland cement grout. The work of erecting the remaining steel is progressing rapidly.

Southern High Service Pipe Line. — Work on the 24-in. water main in Adams St., Milton, has been suspended until spring.

METROPOLITAN WATER AND SEWERAGE BOARD. — *Sewerage Work.* — Work is in progress on Section 69, new Mystic Sewer, at Winchester; on the relief outfall sewer at Nut Island, which consists of 1 400 ft. of 60-in. cast-iron pipe; and on the new screen house at the East Boston Pumping Station.

It is expected that work on the Siphon Crossing, Section 70, High Level sewer, in West Roxbury, will be begun soon.

METROPOLITAN PARK COMMISSION. — The following work is in progress:

Charles River Reservation. — Repairs to No. Beacon St. bridge and draw.

Middlesex Fells Parkway. — Reconstruction of burned portion of Wellington Bridge.

Revere Beach Reservation. — Construction of reinforced concrete shore protection.

Winthrop Shore Reservation. — Construction of sea wall at northerly end of reservation.

Directors of the Port of Boston. — *Commonwealth Pier 5.* — Tests have been made of the electrically operated fire pumps, and the erection of steel supports for cargo hoists is practically completed.

Commonwealth Pier 6 (Fish Pier). — Contract has been let to W. H. Ellis & Son Co. for building wooden pile breakwater about 1 300 ft. long on easterly side of this pier.

Railroad tracks are being laid on each side of center driveway of the pier in front of the Cold Storage and Power Buildings.

Dry Dock. — Bulkheads. Work on the bulkheads is progressing with a small force.

Dredging. The suction dredge *Tampa* is filling bulkheads through 20-in. pipe line about 2 000 ft. long at the rate of 80 000 to 100 000 cu. yds. per mo. The filling of the North Bulkhead is about seventy-five per cent. completed.

Borings. Additional borings are being taken over the dry dock site, and earth cores 3 in. in diameter and rock cores 2 in. in diameter are being obtained.

Dredging. — Three dredges are at work in Dorchester Bay opposite Commercial Point, making 12 ft. at mean low water over the main portion, and a 6-ft. channel to the Dorchester Yacht Club is being dredged.

One dredge has worked part of the month opposite Central Wharf, making 26 ft. at mean low water.

Boston Transit Commission. — *Boylston Street Subway.* — This subway was completed and opened for public travel, October 3, 1914.

Dorchester Tunnel. — Section B includes the station in Summer St., which extends from near Washington St. east to Arch St. Work is now progressing on the interior finish of the station.

Section C is located in Summer St. and extends from near Arch St. to Dewey Sq., a distance of about 1 018 ft. About two thirds of its length is to be built by tunneling, working from shafts. The structure is being built of reinforced concrete. The open-cut portion of the contract is finished. Work is now in progress on the easterly end of the tunnel section. The James J. Coughlan Co. is the contractor.

Section D includes the station in Dewey Sq. and about 400 ft. of tunnel in Summer St., east of Dewey Sq. Work is at present progressing on the station, which is being done by open-cut. The Hugh Nawn Contracting Co. is the contractor.

Bids will be opened on December 15, 1914, for the construction of Section E. This section extends from a point in Summer St. about 600 ft. east of Dewey Sq. to a point near the intersection of West Second St. and Dorchester Ave. in South Boston, and will have a total length of 3 200 ft. About 3 000 ft. will be built by means of shields, 2 100 ft. of this portion being under Fort Point Channel, where compressed air will be used.

Enlargement of Park Street Station. — The enlargement of the Park Street Station was begun on August 7, 1914. The work is especially difficult as it is necessary to complete it without interruption to traffic in the subway. The westerly Park Street platform, for southbound cars, is being straightened and lengthened toward the south about 118 ft. and widened so that its width will average about 22 ft. The location of the southerly entrance and exit to this platform will be changed to the southerly end of the new platform.

The easterly platform, for northbound cars, will be straightened and lengthened about 28 ft. and the narrowest part, or the southern end, will be about 11.5 ft. wide. Changes in the southerly entrance and exit of this platform will be made, but the location will remain the same.

The two westerly tracks in the subway south of the present station platform have been changed to their new permanent location.

The work of erecting new columns and girders in the part of the subway vacated by the removal of the westerly tracks is now in progress. Coleman Brothers are the contractors.

East Boston Tunnel Extension. — In order to reconstruct the tunnel between Washington St. and Cornhill, the running of the cars in this portion has been discontinued, Devonshire Street Station being made the temporary terminus. The old invert is being cut out and the new side walls built between Franklin Ave. and Cornhill. The portion of the tunnel in Scollay Sq. and Court St., between Cornhill and Stoddard St., except the interior finish, stairways and coverings, has been practically completed. Isaac Blair & Company, Inc., are the contractors for this section (Section G).

Section H, which extends in Court and Cambridge streets, from Stoddard to Staniford St., has been completed except the interior finish and stairways at the Bowdoin station. Coleman Brothers are the contractors.

City of Boston. — PUBLIC WORKS DEPARTMENT, HIGHWAY DIVISION, PAVING SERVICE. — Work is in progress on the following streets:

Station St., Columbus Ave. to Parker St., bitulithic.
Frankfort St., Neptune Rd. to Bennington St., bituminous macadam.
Washington St., Cambridge St. to Union St., artificial stone.
Long Ave., Commonwealth Ave. to Allston St., asphalt.
Clement Ave., Meredith St. to Anawan Ave., bituminous macadam.
Rowe St., Ashland St. to Brown Ave., bituminous macadam.
Houston St., Montview St. to Crest St., bituminous macadam.
Edgemont St., South St. to Ainsworth St., bituminous macadam.
Washington St., Mora St. to Armandine St., bitulithic.
Seaver St., Blue Hill Ave. to Walnut Ave., widening.
Queen St., King St. to Claymont St., bituminous macadam.
Browning Ave., Bernard St. to Wales St., bitulithic.
Bourneside St., Park St. to Melville Ave., bituminous macadam.
Langdon St., Norfolk Ave. to George St., Hassam block.
Jewett St., Neponset Ave. to Mt. Hope St., bituminous macadam.
Whitfield St., Talbot Ave. to Norfolk St., asphalt.

PUBLIC WORKS DEPARTMENT, SEWER AND WATER DIVISION, SEWER SERVICE. — *Union Park Street Pumping Station*, building up to roof level, traveling crane in place.

Milton Street Pumping Station (Hyde Park). — Ejector machinery being installed.

Davenport Brook Conduit. — Work in progress between Adams and Wessex streets, and in Codman and Magdala streets, Dorchester.

New York, New Haven & Hartford Railroad. — Clinton Mass. Elimination of Grade Crossings. — Work on the B. & M. R. R. now in progress is the erection of a passenger station. The work on the N. Y., N. H. & H. R. R. is practically completed.

Aberthaw Construction Company. — Quincy, Mass. — For the Fore River Shipbuilding Corporation, the Aberthaw Construction Co. is building a four-story storage shed of structural steel, brick and concrete. They are under agreement to deliver this building in three months, and are working night and day shifts to accomplish this. The interesting feature of this work is the schedule of the very careful and minute planning of each move on the job with the time this must be begun and finished. The Boston Bridge Works have got steel from stock, and are fabricating the Bethlehem sections which make up the frame.

The Fore River Shipbuilding Co., Quincy, Mass., has the following work in progress:

U. S. Battleship *Nevada*.
U. S. Submarine Tender *Fulton*.
Eight U. S. submarine boats.
U. S. Torpedo Boat Destroyers *Cushing* and *Tucker*.